THE

EXPLORERS', MINERS',

AND

METALLURGISTS' COMPANION.

COMPRISING A PRACTICAL EXPOSITION OF THE VARIOUS DEPARTMENTS OF GEOLOGY EXPLORATION, MINING, ENGINEERING ASSAYING, AND METALLURGY.

BY J. S. PHILLIPS, M. E.

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COMPRISING A PRACTICAL EXPOSITION OF THE VARIOUS DEPARTMENTS OF GEOLOGY, EXPLORATION, MINING, ENGINEERING, ASSAYING, AND METALLURGY.

GEOLOGICAL FORMATIONS OF THE PRIMITIVE EARTH, ITS SECONDARY ROCKS, ITS MINERAL VEINS, MINERALS, METALS, COAL FIELDS, ETC., ETC.

GENERAL COMPOSITION AND PECULIARITIES OF MINERAL VEINS; THEIR COMPORTMENT WITH EACH OTHER, AND WITH CROSS COURSES, DIKES AND SLIDES.

GEOLOGICAL AND MINERALOGICAL CHARACTERISTICS OF THE MOST EXTENSIVE MINING DISTRICTS.

EXPLORATION FOR, AND EXAMINATION OF, MINERAL VEINS.

DISCRIMINATION AND ASSAY OF MINERALS, BY THE MOST AVAILABLE AND PRACTICAL METHODS.

MINING AND MECHANICAL ENGINEERING, ABOVE AND BELOW THE SURFACE, FOR DRESSING OF ORES, DEEP MINING, ETC.

ASSORTING, CRUSHING, AND CONCENTRATION OF ORES.

THE BEST METHODS FOR REDUCING THE MINERALS FOR MARKET, BY ROASTING, MILLING, CHLORIDIZING, SMELTING, AND CHEMICAL TREATMENT.

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NEW METHODS FOR TESTING AND ASSAYING THE BASE AND PRECIOUS METALS. VARIOUS USEFUL TABLES OF THE WEIGHTS, SPECIFIC GRAVITIES AND STRENGTHS OF MATERIALS, ETC., ETC.

INTRODUCTION.

TO THE PROSPECTORS, MINERS, METALLURGISTS, AND MINING CAPITALISTS, OF THE UNITED STATES OF AMERICA, AND THE BRITISH COLONIES.

THE first edition of this work was dedicated to you, for whom it was written ; and I now take renewed pleasure in laying this, the Second Edition, before you, with the hope that it will obtain equally favorable acceptance.

No subject can be selected where a really practical book is so much needed as in the varied field of mining, for the assistance of those who may not be educated in the numerous manipulations appertaining thereto, for more general practice of the several trades and professions is required in the development of mines than for any other business.

The greatest mistakes of American mining have been caused for want of ordinary prudence, in this comparatively new and most difficult occupation; more particularly by commencing too much afresh, and inventing worthless machines and processes, or re-inventing such as had been tried in older countries and abandoned. Instead of profiting by men having the experience of past ages, worthy legitimate practicals have been treated with indifference, whilst interloping clean-fingered theorists have been unduly favored, who having discarded real mining, from deficiency of skill in that department, have played recklessly with new ideas of metallurgy, or worked prematurely where insufficient mineral existed, and far too often not only wasted your last dollar, but inflicted on mining severe retardation.

It may be loudly reiterated for everlasting advantage, that reduction works should not *precede*, but *succeed*, the discovery and exposition by mining of *sufficiently rich and extensive deposits* of mineral for *positive realization of profits*. If you have no corn (or mineral) why the mill? First obtain the grain, then grind into flour.

An honest and qualified expert should have been selected to examine and advise, when after the reserves of mineral had been exposed and proven to exist, properly timed and appropriate reduction works, would have realized profits instead of ruination.

A few pages were introduced into the first edition to describe and explain the capabilities of the "Prospector's Wee Pet"—an automatic assaying machine—and because of its great value for preliminary tests, they are now reprinted. This apparatus was contrived especially for, and dedicated to Explorers, whom I admire for their indomitable energy, self-sacrifice and bravery more than any other class engaged in the industrial pursuits; but it will also ascertain the value of rock with sufficient accuracy for all the practical purposes—not strictly commercial—throughout the departments of mining and metallurgy.

Having a knowledge of all the other methods for assaying, and their comparative uselessness for the *mountain purposes* of the novice, and even for the professed operator when traveling, or camping out, I have contrived this machine as the ever ready means for elevating all ordinary men, after a few hours instruction, when aided by these mechanical facilities and general principles, to the level of the expert by any other method for such itinerant purposes; whilst the whole apparatus, with tools, fluxes, calculating strips, weighing and calculating lever, weights, etc., etc., are packed for traveling within a cube of five inches, being only about seven pounds weight. As the cost for making an assay for gold, silver, copper or lead, does not exceed ten cents, such men may actually make thousands of assays which could not be otherwise afforded or accomplished. It is also completely fitted for the discrimination of minerals, and in the absence of numerous and more expensive apparatus, it may be used for all the purposes of analysis, as the fusion of 10 or 20 grains in a crucible, with or without fluxes; for roasting, test tubing, ignition and sublimation; or to dry, evaporate, boil, distill, filter, etc. The single critic who found fault that a few pages out of 672 had been used to describe this useful machine, because it was the invention of the author, gave it

superlative praise in the same breath, and therefore showed insufficient reason for excluding its advantages from the world.

The original intention was to write but a small Prospectors' pocket guide, and in it full instructions for this apparatus, so that sufficient aid should accompany them to prevent such disastrous initial mistakes and final losses; but the work has been extended to 672 pages, to embrace the whole field of mining, which is sufficiently hazardous at best, with too many blanks for a prize, to sustain such unnecessary errors from insufficient examination. A retrospection of the past will show that hundreds of mills have been erected, as enormously expensive assaying machines, but to prove, what should have been then known, that the veins were either insufficiently developed or utterly worthless.

As this is more especially written for a companion and assistant of uneducated practicals, to benefit them and mining, by dealing with such subjects and mineral combinations only as will require their attention, the stereotyped phrases of books, are not repeated here, but plain terms have been put forward for such men's "living present" requirements.

Many books have been written on metallurgy, and very few on mining, which are but theoretical, confined to one subject, or more of a general, historically interesting, or statistical import, than of practical value for miners. In such works little has been said of the peculiar geology of mineral bearing rocks, or of the indicative features of mineralized sections, less of the underground operations of mining, and nothing of that most imperative and effective lever, its mechanical engineering, either above, or below, the surface.

This was written to fill these blanks, to meet the requirements of new countries, and therefore in many instances entirely new ground has been trailed, and departments explained which have not been previously exposed by less practical writers. The constant aim has been to aid practical mining in every relevant way, so that only the few really necessary and best means, methods, machines, and processes, have been selected; instead of giving more elaborate, costly and confusing descriptions of all.

The geological chapters are somewhat speculative and written more for the miner, who should understand the nature of

rocks and positions of minerals, than for conformity with the older writers (or what is termed geological accuracy), so as to give more general ideas of the various formations.

Some hard criticisms were expected, and one or two received, for these bold innovations, but as I believed in their solid basis they were printed, and it is now very gratifying to see that exactly similar fundamental principles to my "whimsical ideas" and "absurd notions" then published, have been since promulgated by Mr. Robert Mallet, F. R. S., the celebrated English seismologist, in a work just issued, which have been more approved by scientists throughout the world, than any of the old theories.* ‡

The chapters on the comportment peculiarities and indicative features of mineral veins, are derived from long observation, and it is hoped that they will afford some records of value to the amateur, and be interesting to every class of thoughtful miners.

The section on exploration, the miner's first and most important duty, which governs after success or ruin, has been as carefully considered and safely advised.

The section on the discrimination and assay of minerals has been kept as free from formulæ as possible, and it not only contains the best of the old modes, but many novel and more available methods for practical men, so that when the one facility is absent, another will be found present, to suit all the requirements of the mine, the roasting furnace, the mill, the smelting and chloridation works, and the mountain; whilst in that, for the strictly commercial purpose, the more direct, less mystified, and least dangerous means and fluxes have been selected.

In mining and engineering the best plans of operation and machines have been extolled, and the most common errors of the past exposed as beacons for avoidance.

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* Several other quotations might be given in support of the view that Mr. Mallet has been anticipated by Mr. Phillips, but the above will suffice to show that the theory is not so new as Mr. Mallet has supposed.—*Mining Journal, London.*

‡ Many other passages might be quoted to more fully establish the fact of priority (for Mr. Phillips) as above, in setting forth the "new theory" of mountain formations.—*Mining and Scientific Press, San Francisco.*

In the metallurgy of this volume just sufficient has been selected from the most valnable and best established processes for rendering the ores of remote countries more marketable, by crushing, pulverizing, concentrating, roasting, milling, smelting, refining, chloridizing and chemical reductions.

The first edition was written in eight months, during business hours, under most unfavorable circumstances, and having been printed from the original manuscript, showed signs of haste with many imperfections of language; and this second edition is so soon required, that to reduce the price of the book, many of the old forms of type have been retained.

An appendix has been added giving the general mining laws of the United States of America, which will be found convenient for reference, before claims are located, patented, etc. It also contains several useful tables of specific gravities, weights and strengths of materials, etc., etc.; and *two new amateur's methods*, for the more effective qualitative analysis of the useful minerals, and the actual assay of silver ores, or concentrated gold quartz, by the ordinary blowpipe.

British readers will excuse certain portions which only apply to this country, and Americanisms of spelling.

In this exposition of a life's experience, my constant aim has been to render the work interesting and valuable to *practical men* and capitalists, and if at times, in the necessary enumeration of past errors, the lash should be individually felt, it was not thus directed, but intended for the general benefit of miners, that *mining proper* may not be unjustly condemned, but have fairer show for success in the future.

Yours respectfully,

J. S. Phillips M.E.,
San Francisco.

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SECTION I.

GEOLOGY AND MINERALOGY.

CHAPTER I.

FORMATION OF THE EARTH FROM ITS INITIAL CHAOTIC STATE TO THE TIME OF THE PARTIAL ELEVATION AND SOLIDIFICATION OF ITS PRIMITIVE GRANITE MOUNTAINS.

"In the beginning God created the Heaven and the Earth.
"And the earth was without form and void."
Genesis, chap. 1, verses 1, 2.

As a work on mining would be incomplete without some observations on the component parts, general features and age of rocks, three chapters have been introduced to describe the primitive, the azoic, and paleozoic formations.

Theory has not thus far, and probably never will be, of much direct benefit to the matter-of-fact miner, for metallic minerals, who reads the more tangible indicative records, which are unfolded during a life's experience, by shafts and levels of exploration in his *individual* district, of mineral ground. The following is written with full knowledge of these facts, first, for his amusement; and secondly, to enable those who have not been favored by a long experience to know what is meant by the terms so frequently alluded to in this book—*primitive* and *secondary rock formations from primitive elements*, prior to the fossiliferous mud stratifications of after times, which contain but comparatively few of the minerals in sufficient quantities to pay the costs of mining.

The theory advocated by Laplace, that all matter was once in a gaseous state, would infer high temperature and freedom from pressure, with the presence of some other controlling power, unknown to science, to prevent the general

solidification into but one central mass, instead of the innumerable spheres which partake of as many self-rotations and orbitual motions, as accompanied by their satellites, they traverse through the various portions of space.

It will be more than sufficient for our purpose to receive it from the Creator, as hurled from the sun or other source, a ponderable nucleus, enclosed by its adhering molten envelope, and surrounded by the nebulae and gaseous elements which were collected and retained by gravitation, when being tangentially projected, to traverse in an annual orbit around the sun, at a distance governed by its speed, etc., whilst it would continue to revolve around its own axis, as it did when it was first projected: other charges may have succeeded from similar causes, that partaking of corresponding direction and force would arrive within the annular track, and be attracted by the larger body already performing its destined course, which would aggregate—by the retardation and acceleration of the anterior and posterior particles of this nebulous ring—into a continually increasing mass.

After billions of cycles had passed away, when the lighter granitic exterior of the earth became from molten to plastic and partially solid condition, we will consider what actions must have taken place in reference to the general contractions that produced the irregular contour of surface and subterranean cavities. Previous to this it may be safely supposed that the surface of the earth was a regular and comparatively smooth globe, surcharged and enclosed with oxygen, hydrogen, and the other inflammable gases or substances, and being largely fluxed with potash, soda, lithia, lime, magnesia, sulphur, iron and manganese, it must have possessed a well fused molten envelope of granitic slag and surface dross. Until this settled almost to solid rock, it would be drawn by contraction and gravitation directly downwards in close contact to the still molten interior, but at a certain stage of solidification, because it naturally contracted less in cooling than the next interior, hotter mass, this vertical action of the outer crust would almost cease, when the contraction of the molten interior being further accelerated by the evulsion of gaseous elements from the molten state, immensely extensive subterraneous cavities would be formed under the superimposed

spherical segment of granitic crust; which then partaking of lateral thrust, from solidity, the abutments of these vast arches would give way, under the increased pressure, and consequently more plastic condition, and the mountains would be forced upwards at the lines of greatest pressure, where the endurance of the rock was exceeded; or valleys and extensive plains sink, by mere straightening, as the ocean beds, to rest at certain places upon the interior until a repetition ensued.

After the period of the first distortion, the portions forming the present ocean beds, having commenced deviation from spheroidal form, would continue to approach straight lines or planes from contraction alone, and the enormous weight of such portions of crust as the Pacific, Atlantic, and Indian Ocean beds, by acting transversely, with irresistible power, being spheroidal and solid, could do no less than create more mountains in a similar manner, for side room, and from central contraction and weight, cause the simultaneous depression of plains. This principle of force seems substantiated by the facts that the highest mountains form the borderings to the widest oceans all over the world, and the average heights opposite each ocean appear to bear corresponding ratios thereto.

In later times, towards the end of the second, and on to the middle of the third chapter, the principles of downward action of gases and liquids and transferrence of sensible heat of steam into the latent heat of water, would by this disappearance of sensible heat, greatly assist to weigh and cool down these unsupported solid portions, and still continue to straighten the bottom from a spheroidal form towards that of a plane; whilst the mountains would not be thus refrigerated, and from their insignificant, comparative areas and weights they would be retarded in downward travel. If the ocean beds merely sunk but one hundred yards, the whole of the lower portions of the paleozoic formations of the continents would appear as now. These effects may apply to deeper strata in the interior of the earth, so far as contractive pressure and temperature are concerned; and as the earth continued its cooling, other internal hollow globes or spherical sections would in like manner be forming from plastic to solid states, which when compressing laterally as described

in the crumpling of surface mountains, the portions where internal mountains were forming would be crumbled and suddenly forced upwards under the outer shell, whilst the adjoining still solid sections would by consequent circumferential motion then rub violently against the interior of the stable colder outer shell, and produce such motions as earthquakes, a greater degree of heat, and force the pent up molten matter and gaseous elements release through surface volcanoes. Whether this be a true or false theory, it is a fact that granite shrinks much less than most other materials, and as all varieties of matter contract differently, as a rule, the heaviest the most, it follows that the solid portions of the interior must frequently have very large caverns, more particularly under the outer crust; and where the molten state commences, the oxides or chlorides, etc., of the metals may intervene in immense horizontal chambers.*

This removes the difficulty of finding materials of suitable weight to equal the calculated *average* specific gravity that the earth should possess, and will serve for reference to explain many things which will be considered in the chapter on the formation of mineral veins, etc.

If it be admitted that cooling *commenced at the surface*, from *radiation*, or transferrence of *sensible* heat into *latent insensible forms*, by chemical compositions of gaseous elements into liquid and solid forms, or from any other causes, it must follow that this theory of contraction is true; for after the surface became sufficiently cold for solidification and cessation of shrinkage it would be absurd to say that an interior molten globe, of nearly 8,000 miles in diameter, would cease to contract within the more fully contracted and colder, solid shell, the more so because of the continual evulsions of gaseous elements through volcanoes, from decomposition of the fluids of the interior.

It now becomes my interesting and important duty to no-

* The roofs of these extensive chambers are not likely to be of regular form, but are probably very stalactitic, having large, acute angled inverted hills, which being occasionally struck on their different slopes by the discharged matter from the subterranean volcanoes, described in Chapter IV, on earthquakes, they would not only afford the means of propagating the waves in different directions, as governed by the side smitten, but vary the effects, and produce much greater disturbance at the surface.

tice the peculiarities and component parts of the various granitic rocks, herein denominated, for the miner's purpose, primitive formations.

True granite is composed of quartz, feldspar and mica; the feldspar and mica are disseminated as separate crystals in the quartz (which latter but fills the intervening space,) to form a very regularly speckled rock, so differing from all others of a sedimentary or artificial nature that it must have been first fused with soda or potash to a fluid, and the feldspar and mica have then aggregated and crystallized, under the succeeding appropriate affinities, which were eliminated at certain suitable temperatures during the slow refrigeration of the globe, whilst the surplus silicic acid solidified to fill the remaining irregularly formed interstices.

On referring to the Elementary Treatise on Mineralogy by William Phillips, to whom I am indebted for many other compositions of the minerals, as analyzed by renowned chemists, I find that quartz (otherwise called silica, silicic acid, and oxide of silicium) is composed of oxygen 51.95 and silicium 48.05; feldspar, from a comparatively pure specimen, analyzed by Berthier, 64.2 of silica, 16.95 of potash, and 18.4 of alumina; the most simple specimen of mica that has been recorded is that from Brunswick, Maine, analyzed by Thompson, which was composed of 64.44 of silica, 28.84 alumina, 4.4 protoxide of iron, and 1 of water. These constitute granite proper, with the three imperative ingredients comparatively pure; but there are several species of variously colored and constituted granitic rocks, that are also primitive when viewed from the miner's standpoint, which have not only slightly different arrangement of parts, but partake of a great variety of chemical as well as chance mixtures. See chapter on the alphabetically arranged list of minerals, for better recognition of component parts, and to the following quotation from Dana, for descriptions of the granites:

GRANITE.—SYENITE.

"*Granite* consists of the three minerals, quartz, feldspar, and mica. It has a crystalline granular structure, and usually a grayish-white, gray, or flesh-red color, the shade varying with the color of the constituent minerals. When it contains hornblende in place of mica, it is called *syenite;* hornblende resembles mica in these rocks, but the laminæ separate much less easily, and are brittle.

Granite is said to be *micaceous*, *feldspathic*, or *quartzose*, according as the *mica*, *feldspar*, or *quartz* predominates.

It is called *porphyritic* granite, when the feldspar is in large crystals, and appears over a worn surface like thickly scattered white blotches, often rectangular in shape.

Graphic granite has an appearance of small oriental characters over the surface, owing to the angular arrangement of the quartz in the feldspar, or of the feldsdar in the quartz.

When the mica of the granite is wanting, it is then a granular mixture of feldspar and quartz, called *granulite* or *leptynite.*

When the feldspar is replaced by albite it is called *albite* granite. The albite is usually white, but otherwise resembles feldspar. When replaced by talc, it is called *protogine.*

Diorite is a rock of the granitic series, consisting of hornblende and feldspar. Color dark green or greenish-black. Crystalline texture distinct.

GNEISS.

Gneiss has the same constitution as granite, but the mica is more in layers, and the rock has therefore a stratified appearance."

For further illustration, one or all may contain oxide of iron, or manganese, whilst the feldspars of different varieties often contain, in addition to silica, potash and alumina, also soda, lithia, magnesia, lime, oxides of manganese and iron; and mica, in addition to silica and alumina, the oxides of iron and manganese, potash, soda, lithia, lime, fluoric acid, and water.

They appear, therefore, in their more simple and imperative forms, as silicates of alumina; the oxides of iron and manganese being present, from their universal prevalence in nature rather than a chemical necessity for their constitutions; they have, however, considerable coloring properties, whilst the others are indifferent mixtures, happening to be present in such localities during fusion. 977 thousandths ot the rocks are composed of oxygen, silicon, aluminium, potassium, sodium, lithium, calcium, magnesium, iron, manganese, and carbon. Primitive rocks contain all but the last, which fire expelled, and which, with hydrogen, chlorine, fluorine, nitrogen, sulphur, boron, and barium, almost complete the after rock formations.

The constitution of these various granitic rocks expose seven exceedingly interesting and strikingly remarkable features.

First. The enormous quantity of this kind of formation.

Secondly. The amazing amount of solid fixed oxygen in the silica, and silicates, constituting nearly half the weight.

Thirdly. The oxygen is separately combined, in direct or acid forms, with all these minerals.

Fourthly. Oxygen and metallic minerals are alone present.

Fifthly. These minerals are all very difficult to be reduced to the metallic state.

Sixthly. The very lightest metallic elements are those contained in such surface rocks.

Seventhly. The absence of all volatile carbonates, chlorides and sulphates of lime, magnesia, etc., etc.

These, combined with the following facts, substantiate at least the igneous *origin* of this Earth, which partakes of the exact mathematically calculated shape that a fluid of its specific gravity and size would have assumed, when rotated at the same speed (7,926 miles equatorial and 7899.507 miles of polar diameter), and that the temperature increases below the depth of the sun's influence, at the minimum rate of 1° for every 60 feet deeper throughout the whole world, which collectively afford incontrovertible proofs that fire was the mighty subservient power used by the Creator to shape our terrestial globe.

These are the local proofs.

To ignore the sublime agency of fire in the initial casting of the innumerable worlds of the vast universe, we must disbelieve and despise all the facts that are derived from observation, both here and in space; for chemistry, the eye, the telescope, and the spectrum, unfold continual proofs that innumerable spheres are not only now in combustion, but burning exactly similar elements to those of the earth, where water itself must have been thus formed, and the primitive rocks reveal and confirm the effects of fire.

In connection with this theory it is difficult to understand why the gases, which are all so light, are immediately present with the much heavier molten or solid mass, for the continuation of combustion; and it appears from necessity that

all the gases must have the property of becoming liquid or solid under extreme pressure, and may have lain in that original condition, and bursted forth as the pressure is by any means removed. It can be proven to be so in some instances, even under the moderate means we can command, whilst to reverse the action all the solids and fluids can be volatilized.

A good illustration of this may be seen in mercury, for under a slight advance of the temperature of our atmosphere it would have been volatilized from its metallic states of fluidity and solidity and be concealed for ever.

If these rocks were thus formed at high temperatures, amazing quantities of their elements must have been at some period existing in a volatile condition, and if so the whole globe would have been surrounded by this very high, and consequently enormously heavy, elastic atmosphere of such, and the question arises whether the speckled crystallized ingredients of such rocks may not have been actually formed when these free elements were thus supported in this elastic medium, and gradually settled into their bed of silicic acid, just in similar manner to the snow of our much lighter atmosphere. The bed rocks being formed under their natural chemical affinities as the pressure and temperature decreased during exceedingly slow cooling; the snow by cold alone, whilst the principle of support applied alike to both.

During these formations, the earth's crust or hollow shell would continue to be violently compressed in circumferential directions, and being solid it would, from its own gravitation, as it endeavored to follow the still faster contracting interior, crumple and distort certain sections of least resistance into extensive ocean beds, with comparative elevations of rolling surface contour of hill and dale.

In such a state of homogeneity or equality, the partial invasion of volcanic fires had not at this early period *really uplifted* any mountains; but their apparent elevations existed more from the above causes, and a difference of subsidence or *loitering behind* of such portions, during the *general travel*, when urged by contraction and gravitation *towards the center* of the earth.

To make the preceding principle of action still more intelligible it may be supposed that the whole exterior solid and colder shell of the earth has been continually urged downwards by its own unsupported weight, after the hotter and faster contracting interior, and therefore when any large subterranean space has been vacated, that portion which lies above will endeavor to weigh down, or settle thereon, and as soon as this sufficient hollow area creates an ample power from gravitation to crush the necessary side room, by thickening that particular part of the adjoining surface into mountains, this immensely heavy dome of crust being thus released will be thereby allowed to force its way and shift down upon its underlying region. It is not plausible to suppose that the whole crust has at any time descended in the one operation, so that these hollows of power have acted everywhere separately at one time or other, and caused innumerable and most irregular settlings both of mountains and ocean beds; but the latter having been forwarded at the commencement have generally kept a leading position since.

This lateral crushing is imperative, for unless the size of the shell is reduced to that of its enclosed faster contracting contents, it cannot fall to rest thereon.

At this stage of the creation the whole surface would be more or less covered with the deep oxidized dross from a world's fusion, which would be largely composed of soluble soda, lime, magnesia, etc., and all other substances that were either in excess or lacked the necessary affinity for uniting with other constituents which formed the solid *primitive* mountains, and "bottom" of *granitic* "*bed rocks.*"

This would be encompassed by a ponderous mixed atmosphere, composed of all the vapors and gases that fire could create, volatilize, or release, and which were in excess or unnecessary for the compositions of these *primitive* corrugations of the "bottom rock."*

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* In favoring these theories for primitive formations, I would not be misunderstood by religious people; as I am neither atheist nor infidel; the sequence of creation as described in the first chapter of Genesis, conforms in general terms, so wonderfully close with scientific opinions, that the length of days is the only apparent absurdity, and this expression must have been merely figurative.

CHAPTER II.

FORMATION OF THE FIRST CLAY SLATES, GREENSTONES, QUARTZITES, HORNBLENDIC, AND FINE GRAINED FELDSPATHIC MIXTURES, ETC., FROM PRIMITIVE ROCK ELEMENTS.

"And darkness was upon the face of the deep."
Genesis, chap. 1, verse 2.

Here commences an eon of the greatest possible confusion, when probably all the known gases and vapors that the chemical agency of fire could produce, from the but recently fused globe, existed as a voluminous, mixed, heavy, and dark atmospheric envelope, over the incrustations of partially soluble dross, that covered the surface of the refrigerating, but still, red hot, earth.

Under such conditions, who can say what changes might not have been produced from this time until water ceased to boil, under the atmospheric pressure? The various crystalline rock formations, and the apparently extraordinary erodations of the general surface contour, would have been speedily accomplished, and many things, now unnatural, realized.

These principles of pressure and heat have not been sufficiently studied or experimented on by geologists; although they favor the molten and refrigeration theory, and consequently admit that such degrees of heat then existed, they and chemists, have neglected to examine what effects can be chemically produced by the gases, or the alkaline and alkaline earth solutions, under conditions that must have existed during this most puzzling period.

Water, in vapor and liquid, has exerted more controlling influence, and wrought more variously in dissolving, decomposing, disintegrating and modifying the earth's surface, than all other vapors, gases, and liquids combined; and should, therefore, be more elaborately considered in reference to its peculiar characteristics.

It appears to have been the most astounding conception of the Creator, an especial and universally pre-arranged pro-

visional means for accomplishing, uniting, and sustaining all the necessary creations that were intended to be accomplished throughout organic and inorganic nature.

Without water, nothing could have been formed, nothing supported, or continued; it is not only a necessity for all creations and stages of animal and vegetable life, but also of inorganic crystallizations and constitutional forms. It would require volumes even to name the substances with which it is associated, and its many peculiarities; but the following may be profitably remembered.

Water is formed when hydrogen is kindled, either with flame or electric spark, in presence of free oxygen. It is colorless, tasteless, and inodorous. It does not change its state under ordinary circumstances, when free from foreign matter, in any way, during any length of time. It is indestructible, and is not, so far as yet ascertained, within moderate degrees, chemically decomposed by heat—for, although entirely vaporized, it returns, on cooling, to the liquid state, as before, *ad infinitum*. It combines in various forms of basic, dydratic, and saline water, as well as that of crystallization, with more elements than any other known liquid. It is perfectly neutral, possessing neither acid nor basic properties, yet unites with both, and increases their chemical activity. It also combines with neutral salts, in two conditions of crystallization.

Although it possesses neither acid nor alkaline strength, *more* substances are *soluble therein* than in any other liquid; which can be again separated by mere evaporation. The solvent power of *water on solids*, is *generally increased by heat—lime* being one of the exceptions, where it is decreased. At the ordinary temperatures experimented on, magnesia is insoluble in water, although at higher degrees it may not be so. Heat diminishes the solvent power of water for gases, but increased pressure would, to a considerable extent, counteract this, and in some cases reduce gases to liquids, that would act differently. It partakes of the property of evaporating at ordinary temperatures into clouds that are sufficiently heavy to float as vapor in mid air, which by aggregation descend as rain, in wonderfully well regulated quantities. It is the only liquid that varies from the general law of expan-

sion by heat, and contraction by cold; as it continues to contract down to 39° Fahrenheit and then to expand again as the temperature decreases to the freezing point of 32°. Were this not thus so, the ocean would become one mass of ice from equator to pole, as the ice from each freezing would continue to sink to the bottom, until the whole mass was solid, when the sun, acting but on the equatorial surface, would possess but little power to thaw such a tremendous bulk, and the cold become so general that rains would be frozen into snows or hail stones, and all organic nature perish—which is in itself an unmistakable Almighty provision for our safety. It is sufficiently buoyant, that land animals falling therein, may by proper exertion, save their lives. It is also of very suitable floatability and density for the ships of man, which he is enabled by skill to frame and build, but just strong enough to barely resist its momentous effects. Water boils at a degree but just sufficient to cook our food; and freezes at a point that does not seriously interfere with our comfort or general operations. It is the only liquid that would suit the general requirements of the house, the chemist, miner, miller, and engineer, even if others existed in sufficient quantity. It is clean, clear, non-glutinous, is the exactly requisite specific gravity, and can be filtered, evaporated off, or condensed at pleasure. It contains considerably *more latent heat* than *any other* liquid.

When water is boiled in a close vessel over sufficient heat, the first temperature of the boiling point, in a vacuum under no pressure, is but 67 degrees, or 35° above that of freezing; but as the pressure is increased by the formation of steam or by any other means over the liquid, the temperature of the boiling point also increases with a comparative ratio, and the pressure being known, the temperature (which it invariably governs) may be calculated therefrom, or *vice versa.*

The boiling point, under but one atmosphere's pressure, equals, at the sea level, 212°; that is, 180° above the freezing point of 32°. The latent heat of water and steam is estimated at 1000° at the atmospheric pressure. The sums of latent and sensible heats of water are always equal to 1180° in a vacuum, under atmospheric or any other increased

pressure, up to the limit of elasticity of steam; where all that is possible of the latent heat has been expelled into sensible form.

M. M. Dulong and Arago, under a commission from the French Academy, have demonstrated, by actual experiments made, under pressures varying from 1 to 50 atmospheres, that the pressures and temperatures range as follows: Taking for our purpose the intermediate figures which stand opposite every advance of 5 atmospheres, and starting from the boiling point in vacuum, it reads thus:

Boiling point in vacuum under a pressure of	0	atmosphere..............67°
" " " " "	5	atmospheres,...........307.5°
" " " " "	10	" ....358.28°
" " " " "	15	" ....392.46°
" " " " "	20	" ....418.46°
" " " " "	25	" ....439.34°
" " " " "	30	" ....457.16°
" " " " "	35	" ....472.73°
" " " " "	40	" ....486.59°
" " " " "	45	" ....499.14°
" " " " "	50	" ....510.60°

So far we have thus well established these practical steps n a series commencing with the sums of 67° sensible heat and 1113° of latent heat, which =1180°, and ending with the *sensible heat* of 510.6°, and but 669.4° latent heat, thus created by heat under 50 atmospheres of pressure, or about 750 lbs. per square inch, and ending God only knows where.

Now we will consider what effect this principle must have exerted on the earlier surface formations of our globe, when this vapor of water was mixed with all the other gases that were simultaneously created by fire. First, it is thus shown that a sufficient amount of pressure and heat will increase the sensible heat of water, so as to not only render many things very much more soluble, but to actually melt, at least some, of the metals. That such states of transient pressure and heat existed at a certain period, cannot be denied by those who admit the theory of primitive heat formations, as all must have passed through these degrees from that of fusion to the present.

As water possesses so many other peculiarities, may it not have the additional intentional provision of becoming again

liquid, or be reduced to hydrogen, under certain pressure and heat, thereby affording the nucleus of central fuel for the formation of worlds, and their elementary surface compounds, when and where required, as the pressure is removed, at the proper degree of temperature, and ignition or oxidation of this, thus formed, metallic hydrogen ensues.

It may be possible that the vapor again liquifies or solidifies, after losing all its latent heat, under sufficient pressure; and on the release of pressure the elements of hydrogen and oxygen may become free, and re-unite when ignited as the vapor of water, whilst the excess of oxygen would form its union with bed rocks, and supply that in the present atmosphere.

Since the date of first edition, wherein the above remarks were published, those astounding explosions of burning hydrogen from the sun, to some 200,000 miles above its surface, prove as thoroughly as can be possible, that solid hydrogen must exist in its interior, and thus supply the fuel for its formation. If this is so in the sun may it not be acting in a like manner, but with less power, in our globe, and thus create volcanic force, which by bursting occasionally under certain portions of the crust as described in the fourth chapter, produces earthquakes, and accounts for the formation and presence of water as discharged through red hot craters.

Now the total areas of the oceans equal eight-elevenths of the surface of the earth, and as they have an average depth of three miles, it follows that the depth, if extended over the whole globe, would be more than two miles, or 10.560 feet. Taking the round number of 30 feet high of water as the representative of one atmosphere, and dividing the 10.560 feet thereby, we have 352 atmospheres of average pressure over the whole bed surface of the earth, which is more than seven times the pressure experimented on by the French Academy. Now if this amount of water was converted into vapor over the red hot earth, or was first formed as vapor (which seems the more plausible), it would, as a matter of course, being transferred from under to an overlying equal weight, exert the same pressure of 352 atmospheres, which the numerous other gases would increase to a still higher pressure, subject to some deductions for increasing length of

circumference with greater altitude, etc., from divergence.

It appears, therefore, very certain that a much higher sensible temperature (which is governed by pressure on steam and water,) existed at some more remote period than the 510° under 50 atmospheres, even surpassing the modulus of elasticity of steam; whilst the underlying saline solution in surface water, if any then existed, would exceed red heat.

These expressions are founded on the examination of pure water, but the degree is much increased when it contains other substances in solution. We will suppose that lime chloride may have largely composed one of the first saturated solutions from the released elements of fusion; as the escaping chlorine gas would exist, under more than 4 atmospheres of pressure, only as a liquid, that would form various chlorine compounds at more moderate temperatures.

This saturated solution alone, even at the present pressure of but one atmosphere, increases the boiling point from 212° to 264°, but all other freed gases and liquids which unite with water, as well as all the first exudations of solid substances that were soluble therein, at the extremely high temperature then existing (which would embrace many that are now insoluble,) would still further increase the boiling point; so that the trials of Dulong and Arago of pure water, which reached 510.6° under but 50 atmospheres, would in all probability have extended the degree of this then comparatively small and mixed solution to some 700° or 800° without further pressure. This appears but insignificant when compared to that which must have been then in action under the enormous influence of this vapor, increased still further by the following gases.

Oxygen, nitrogen, and hydrogen must have existed in enormous quantities, either uncombined as oxygen and nitrogen of the atmosphere, or in combination as the oxygen and hydrogen in steam, or in the more intensely heated and compressed unknown forms previously alluded to. Sulphurous acid, and carbonic oxide—changed to carbonic acid by combustion in air—must have been present, in gaseous conditions, as it is well known that they could not exist at any such temperatures, when combined as they are now.

Chlorine would for these same reasons have been present

in immense quantity, either as a gas, or liquified (at ordinary temperature) under a pressure of four atmospheres, but more probably as a gas,—for increased temperature would also require increased pressure for its liquification—this is, however, immaterial, as both carbonic acid and chloric gases, being heavier than the others, would form carbonated and chloridated steam to fall as water for further reactions, forming, at the suitably tepid periods, the various carbonates of lime, magnesia, etc., and the chlorides of sodium, etc. Whilst the sulphurous acid would unite with the steam to fall in eroding showers, producing solution, to combine with the other more suitable surface elements.

These are but a few of the gases which, with steam, composed this voluminous, mixed, heavy, and dark primeval atmosphere that surrounded the earth at this period. It affords interesting wonder as to whence all these gases proceeded. It is reasonable to suppose, that when a globe appears in luminosity and apparent combustion, that one or more of the inflammable gases must be present to support it; and strange as it may seem, the spectrum has recently demonstrated, by actual qualitative analysis, from the colors produced from mineral flames, that the sun, other fixed stars, and nebulous belts, are burning, or oxidizing, at this very moment hydrogen, sodium, calcium, magnesium, iron, manganese, nickel, cobalt, chromium, titanium, etc., etc.

Whether the nebulous theory is approximately correct for solids, or not, some of the gaseous elements may have existed in very much more remote space than now; for just at the present state of rarefaction, we fail to even conceive the amazing amount that have condensed from the gaseous, voluminous, and elastic, to the compact liquid and solid states; so that much of the intervening spaces may have been occupied by oxygen, nitrogen, or other more or less attenuated gases, collected by the attraction of the different spheres that traversed their respective orbits in space.

In connection with this theory of fire, it appears most strange as to what caused refrigeration; and in addition to radiation I see no better reason, than that the heat may have been transferred from the sensible to latent form, during the numerous chemical changes from gaseous to liquid and solid

states. For instance, when hydrogen is burned, as it is commonly called, in the presence of oxygen, these gases combine to form water (its only apparent source), which contains, under one atmosphere's pressure, but 180° of sensible heat, and 1,000° of latent heat; so that this considerable ratio having been thus stowed away from sensible forms, refrigeration was the consequence.

If this idea is a generally correct one, the various gases, by being composed into liquids and solids, would hasten the cooling, during this particular period of formation, to a very remarkable degree.

Notwithstanding this more speedy refrigeration, a very long, hot period must have elapsed, as the first slates were being distributed and deposited, before the temperature would be sufficiently reduced for the formations of the inorganic crystalline carbonates of lime, magnesia, etc., with the confused mixtures of slates that preceded the more tranquil periods, when water ceased to boil under permanent minimum atmospheric pressure.

It would be as absurd to suppose that changes were not then taking place, as that fish or animals of any kind could have existed during this hot epoch.

THE FORMATION OF THE EARLIEST CRYSTALLINE CLAY SLATES, FROM PRIMITIVE GRANITIC ELEMENTS.

In this state of wild confusion of gases and vapors, general debris and dross, that encompassed the earth at this time, under the ever-varying actions of fire at the different parts of the surface, vast volumes of steam and accompanying vapors would be forced upwards from highly-heated oceans, seas, and lakes; which would create tremendously violent hurricanes of the compressed and heavy gases, that would sweep over the land with a distributing power far surpassing anything that can be conceived possible from the present ordinary causes for winds; thus scattering much spray from the hot oceans over the mountains, and the comparatively light, thick debris,—that would even float in such an atmosphere,—over the slopes into the lower grounds, which, by continued attrition, would wear into powder the more exposed and larger granitic rocks; whilst the moist

steam and hot rains would carry away, in mechanical and chemical solutions, immense quantities of soda, lime, magnesia, etc, to these primeval ocean reservoirs, for subsequent reactions, precipitations and sedimentary depositions.

Large quantities of these substances must have been generally disseminated throughout, and dissolved from, this surface scum, by highly heated water, that would by rendering the mass more cellular, hasten the disintegration and distribution of the quartz, feldspar, and mica, which may have been, under such circumstances, transferred by the ponderous winds, to form the gneissose granites; and by further pulverization, or naturally smaller crystals, the earliest crystalline clay slates, as secondary formations, from primitive elements, on the irregular corrugations of the primitive bottom rocks, described in Chapter I.

I think the effects produced by floatation, in such a dense mixture of all the elements that fire could release, have been insufficiently credited; for, surely, an elastic medium of this enormous density must have held amazing quantities of the rock debris in mechanical suspension; and, as our one atmosphere's density floats a feather and impalpable dust, it cannot be doubted that such as must have then existed, when assisted by ponderous winds, would have floated the sands, or even the loose rocks themselves, into the more tranquil slopes and valleys. It also seems possible that many free elements may have been thus suspended to combine, by chemical crystallization, into heavier solid forms, to fall in continual showers, and aggregate, in course of time, into the Azoic bed-rock. This would fully account for gneiss and other formations, that are now but subjects for controversy and conjecture.

In this connection, the quartz may have acted as a receiving solution. As silicic acid forms the half of all rocks, and enters, *as an acid*, into their constitutions to form silicates, may it not be possible, and even probable, that the components of water were created as its diluting associate, under extreme pressure and temperature exceeding that of its modulus of elasticity, and that, after the pressure became sufficiently reduced, the silicious solution was evaporated by the very creation of the vapor of water, by inverse means, and this peculiar crystallization was the residual result?

In connection with these distributions and depositions of the crystalline azoic formations, most of which, I think, were deposited before water ceased to boil, two very important facts must not be forgotten, that the first upheavals of all the primitive mountains, at this period, compared with the subsidence of the ocean-beds, were by no means so different as they now are in their elevation and depression, nor were the hot oceans anything like, in extent and depth, what they have since, by condensation of steam, become; so that, for these reasons, the very hot ocean waters may at the earliest periods have had the separating barriers of the old and new world's continents, just as they have at present, with but the difference in the depths of the water as compared to later periods, and by partaking of but the slight tidal motion that is now produced by the action of the moon, the distributions and sediments would be settled in situations that conformed to such conditions; but, as the earth continued to refrigerate, the vapor of water would condense, and increase the oceans so much that the waters thereof would ultimately submerge all the lower lands of the present continents of the world, leaving nothing above it but a few peaks and comparatively short ranges of the tops of the mountains as mere islands. The ocean water having risen from its minimum depth, and surmounted its barriers, followed the moon's accelerative attraction, and wrought at its maximum elevation, uncontrolled sway on the general surface debris, and thus deposited its various azoic (non-fossiliferous) rocks at all levels during its ebb from the land; so that the mountain regions continued to increase as the ocean-beds subsided and withdrew the waters therefrom.

It may be here repeated that a subsidence of the ocean's vast comparative areas, of but 100 yards, would have laid bare all the low lands of the world. This liquid reservoir and distributor of mud, aided by contraction and its consequences, acting in conjunction with chemical solvents, the mechanical disintegrators of ponderous winds, and the enormously plentiful deluges of rain, during this period of steam, shaped the transverse hills and valleys of the primitive rocks, and with their debris reformed what the miner must understand as the *first secondary rocks*, from primitive

rock-elements, being the latter stage of this peculiar azoic formation. These rocks are all of crystalline appearance, and apart from the fineness of the grain, and the presence of talc, extra mica, hornblende, etc., do not materially differ from the composition of the granites, from which they are derived. Crystallization, with the absence of too perfect cleavage, and fossiliferous remains, are imperative characteristics of this age of formation.

There is, also, the compact variety of crystalline carbonate of lime, granular limestone, which was probably deposited at or toward the termination of the period, from the chemical solution of chloride of lime, as the temperature of the boiling solution became sufficiently reduced for the carbonic acid from the atmosphere, or from the hot water, to unite therewith and precipitate it as carbonate of lime, the chlorine being released to form chlorine water for other combinations, as that of sodium, etc.

These limestones, being formed during the hot period, consequently lack fossils and cleavage, and frequently form irregular combinations, as would have been expected, with the other mechanical ingredients from neighboring rocks. These must not be confounded with the modern coralline and stratified mud formations, in which well-formed, perfect fossils abound. For the miner's purpose, the rocks and deposits, described in these chapters, will embrace all the massive granular kinds, as the various granitic rocks, crystalline slates, and limes, as well as the hard greenstones, and some of the porphyries that are known to be of settled formation, and not produced by the more modern, immediately direct local volcanic action; extensive dikes, or broad belts of hornblende or hornblendic slates; chlorite slate; or their conglomerates, when adjoining the bottom primitives; most especially when they are stained by the oxide of iron or other minerals.

As these elements were all formed by fusion, during the evulsion of the minerals, they were more or less impregnated therewith at the time, and what happened to be volatilized, and escaped into the atmosphere, were sooner or later again collected and reconveyed to the general solution, that, at

the proper time, deposited the base mineral oxides upon this only bottom receptacle of progressive formation, and which formed the general stock of the salifiable bases that in due time were transferred to the veins of future ages, and precipitated by the many re-agents that were present during long periods of time.

The metals that have been profitably extracted from the true fissure veins of these formations, are chiefly iron, copper, tin, lead, zinc, and silver in combination with copper or lead; but, less frequently, the ores of silver, in such settled positions.

When intrusive and comparatively recent volcanic action *approaches the junctions* of these primitive and secondary formations, silver is more frequently found in its constitutional forms, and in greater abundance, than when it is *very far* removed from such action.

Gold has been found in profitable quantities in such primitive, or primo-secondaries, when volcanic action has uplifted, distorted and tilted the latter strata to a considerable angle; sometimes it is then found in the primitive, very near the junction, but much more frequently in the clay slates. Silver appears to have been of more recent formation, and, as but little of it will suffice for profits, it has been consequently worked from more numerous strata than many of the more plentiful base minerals. I have often thought that, during the period of the general volatilization of all of the minerals and metals, there may have arisen just as much silver and gold as some others of the less plentiful metals; but, when the surface reactions commenced, silver if not a chloride would unite with some *soluble chloride*, as chloride of sodium, to an *everlastingly insoluble* chloride of silver, that would be dispersed with the bed-rock formations, but, being insoluble, would never be transferred to, and collected in, veins or pockets for profitable extraction, as is the case with the many soluble base minerals. Gold would, also, from being soluble in chlorine, or chlorine water, be mostly dispersed throughout the ocean, or precipitated in after times into infinitesimally small metallic particles, that would, also, be forever insoluble in any other natural solvent, after the

chlorine had united to other elements, for which it possessed a stronger affinity, than for gold.

The shell of the earth continued to crush laterally, to create room for its settlement on the molten, faster-contracting interior, during these formations, as it did in the primitive period; and in both cases, as would be supposed, not in a very universally regular manner; so that the primitive secondary Azoic deposits do but seldom conform to or cover the primitive bottom, in any very equal layers over the mountainous districts of greatest disturbance, wherein the miner requires information. These Azoic formations have been, were being, and would continue to dry and bake into concreted rock, by the under-lying heat, during the after-deposition of the Paleozoic, Mesozoic, and Cenozoic, times; and the distorting influences would also be occasionally acting, in a more moderate scale, to its further displacement, as may be seen in the formations of all ages.*

* At about this and subsequent periods, it frequently happened that the overlying azoic rocks *slid upon* the primitive bottom of granite, when the latter was being crushed and thickened into mountains; and in a manner sometimes toothed into, or doubled back against such elevations; or in other words continued with the horizontal motion of the general adjoining rock until it arrived at about where the partial thickening of the granite occurred, when such extraordinary distortions and strange foldings resulted as to render the old theories for the *direct upheaval* of mountains quite inadequate for the effects produced; for nothing but *directly lateral separate shifts* could have caused the very irregular features of the crushed or crumbled broken granite, and the various jumblings of forms of the secondary strata, which are occasionally seen by the practical miner.

CHAPTER III.

THE ROCK FORMATIONS OF THE PALEOZOIC, MESOZOIC AND CENOZOIC TIMES—WHERE FOSSILIFEROUS REMAINS OF BIRDS, FISHES, AND ANIMALS ARE FOUND.

"And the spirit of God moved upon the face of the waters,"
"And God said let there be light: and there was light."
Genesis, chap. I, verses 2 and 3.

The preparatory stages of rock formations described in Chapters I and II, may have required billions of years to accomplish, and as plainly shown by the quotations from Genesis, this long dark entire time, preceded the first day's, (or period's) light, and week's work of organic creation.

These life sustaining times, now to be described, have been subdivided by geologists into ages, and the ages into eras, and periods.

The Paleozoic Time is the only one of these that concerns the miner; the others should be studied but for recognition, and avoidance. This commenced an era of more tranquil and natural formations, when water had ceased to boil, under an atmosphere that approached more closely to the present; when the lower order of living creatures could exist, and leave their records embedded in a softer stratified mud, to solidify and seal for the future inspection of the Almighty's master creation, Man. This mud solution was principally such as was not chemically precipitated, or was too impalpable for settling during the period of ebullition, and which contained, in solution, those elements that were still partially or wholly soluble in tepid water; some of which would be precipitated on cooling, whilst the remainder supplied the organisms with lime, etc., for the formations of the modern coralline and stratified rocks, that now overlie those of the

Azoic crystalline deposits, which more immediately concern the miner of metallic minerals.

"And God made the firmament, and divided the waters which *were* under the firmament from the waters which *were* above the firmament."

Genesis, chap. I, verse 7.

"And God said let the earth bring forth grass, the herb yielding seed, *and* the fruit tree yielding fruit after its kind, whose seed is in itself upon the earth."

Genesis, chap I, verse 11.

"And God said let the waters bring forth abundantly the moving creature that hath life, and fowl *that* may fly above the earth in the open firmament of heaven."* *Genesis*, chap. I, verse 20.

This Paleozoic Time (of stratified rocks, and these organic creations) embraces the Silurian Age of Mollusks, the Devonian Age of Fishes, and the Carboniferous Age of the Coal-field Deposits. The Silurian Age is again divided into the Lower Silurian and Upper Silurian Eras, the first embraces the Potsdam, Trenton, and Hudson Periods; the first, or Potsdam, being composed of Potsdam sandstone and calciferous sand-rock; the Trenton, or second, of Chazy limestone, and Trenton, Black River and Bird's-eye limestones; the Hudson, or Third Period, of Utica shale and Hudson River Group; whilst the Upper Silurian Era embraces the Niagara, Salina, and Lower Helderberg Periods, the Niagara Period being composed of Oneida conglomerate, Medina sandstone, with the Clinton and Niagara Groups; the Salina Period principally of saliferous beds; and the Lower Helderberg Period of the Lower Helderberg Group of Aymestry limestone. The Devonian Age of Fishes, embracing the Old Red Sandstone, is divided into the Oriskany, Corniferous, Hamilton, Chemung and Catskill Periods; the Oriskany Period being composed of Oriskany sandstone; the Corniferous Period of Cauda-Galli grit, Schoharie grit, and Upper Helderberg limestones; the Hamilton Period of Marcellus shale, Hamilton Group, and Genesee slate; the Chemung Period of the Portage and Chemung Groups; and the Catskill Period of Catskill red sandstones.

The Lower and Upper Silurian formations, when near to or adjoining the Azoic primitive or secondary primitive rocks, and when comparatively free from well-defined fossils, other

* It is very remarkable that only fishes and fowls were first made,—which strictly conforms with the instable condition of the dry land,—for as man and animals could not exist and multiply on ground that must have been, at this time, too frequently submerged, they were necessarily the last of creation.

suitable conditions being present, frequently have veins that contain profitable quantities of lead, antimony, zinc, and iron; and when slightly invaded, and metamorphosed or tilted by more recent volcanic action, pockets of silver are often found in both carbonate of lime and the combined carbonates of lime and magnesia, as well as in the clay slates.

When talcose, chloritic, and ordinary clay slates have been thus tilted for a considerable distance, and uplifted as a margin to an ancient ocean, gold has been found in greatest profusion throughout the world, in reefs that accompany the divisions of the stratum, rather than in true fissure veins; but those which deviate from the general line of strata, and take their own route at times and places, have been much more profitable than others that always conform thereto.

The Carboniferous Age terminates the Paleozoic Time, and is divided into the Sub-carboniferous, Carboniferous and Permian Periods; first, the Sub-carboniferous, of sub-carboniferous or mountain limestone and millstone grit; the Carboniferous, of the various series of strata of the coal measures; and the Permian Period of the Permian Groups of red sandstone and marls, with magnesian limestone.

The formations of these Carboniferous Ages should be closely studied by the coal-miner, and the recorded facts laid down in numerous geological treatises, regarding the ages of the fossil shells, must be often referred to, that he may know when he is, or is not, on ground that may contain or cover coal-beds, as well as the particular position for the different periods of the deposits on the same field, so that errors may be prevented.

It would require much space to fully illustrate this subject, which, to be beneficial, should be exhaustive. I have, however, made the following extracts from Dana's *Manual of Geology*, to expose the general characteristics, and immense extent of the American coal-fields, already discovered; and, for further information on this subject, I would refer to the other books written for practical coal-miners.

"EPOCH OF THE COAL MEASURES.

I. DISTRIBUTION OF THE COAL AREAS.

"1. The great *Appalachian* coal field, covering parts of Pennsylvania, Ohio, Virginia, eastern Kentucky, eastern Tennessee, and Alabama. The workable area is estimated at 60,000 square miles. The whole thickness of the formation

is 2500 or 3000 feet: aggregate thickness of the included coal-beds, over 120 feet in the Pottsville and Tamaqua Valley, about 62 feet near Wilkesbarre, 25½ feet at Pittsburg. The area is partly broken up into patches in Pennsylvania. in the centre of the State, between Pottsville and Wyoming, are the famous anthracite beds, divided into many distinct patches; and in the western part commences the great bituminous coal-field which spreads into Ohio and stretches on south to Alabama.

"2. The *Illinois and Missouri*, covering a very considerable part of Illinois, part of Indiana and Kentucky, and, west of the Mississippi, portions of Iowa, Missouri, Kansas, and Arkansas. Estimated area, 60,000 square miles. Whole thickness of the formation, in Missouri, 600 to 1000 feet; in western Kentucky, nearly 3300 feet—with about 70 feet for the aggregate thickness of the coal-beds.

"3. *Michigan*, situated about the centre of the peninsula. Estimated area, about 5000 square miles. Whole thickness of the formation, 123 feet; rests upon a sandstone, probably of the Millstone grit epoch, which is 105 feet thick.

"4. The *Texas*, covering several of the northern and northwestern counties.

"5. The *Rhode Island*, lying between Providence and Worcester in Massachusetts, and opened at Cumberland north of Providence, at Portsmouth 23 miles south, and also showing thin seams at Newport and elsewhere; in Massachusetts, outcropping at Mansfield, 15 miles northeast of Providence, at Wrentham, 5 miles from Mansfield, and at Worcester. Estimated area, 1000 square miles.

"6. The *New Brunswick and Nova Scotia*, covering part of New Brunswick, Nova Scotia, Prince Edward's Island, and Newfoundland. Estimated area, 18,000 square miles. Whole thickness of the formation at the Joggins, including the beds of the Millstone grit epoch, 14,570 feet; the number of included coal-beds is 76, some of them being very thin, and the aggregate thickness 45 feet. (Logan.) These coal-beds are situated in a part of the Coal measures, 2819 feet thick, near the middle of the series. At Pictou there are six beds of coal, with an aggregate thickness of 80 feet. (Dawson.)

"The total number of square miles of all the productive coal-fields of the United States is 125,000.

"Besides the above, there is the *Arctic* Coal region, which has been observed on Melville and Bathurst Islands, Banks Land, etc., and the *Rocky Mountains*, both of which are yet unexplored.

"Limestones of the Carboniferous period—formerly supposed to be Subcarboniferous—have a wide distribution over the summit and both the eastern and western slopes of the mountains. This limestone has been observed at the Black Hills in Dakota, and the Laramie Range; about the head-waters of the Missouri; at the South Pass of the Rocky Mountains; in the ranges south of Pike's Peak, and east and west of Santa Fé, New Mexico; in the great basin of the Colorado; and it probably underlies to a considerable extent the Mesozoic rocks of the Rocky Mountain slopes west of the Mississippi.

II. ROCKS.

"1. *Kinds of rocks, and stratifications.*—The coal measures include stratified rocks of all kinds—sandstones, conglomerates, shales, shaly sandstones, limestones; and the limestones are generally impure, or magnesian. There is the same wide diversity that occurs in the Devonian, with more numerous and rapid transitions than were common in that age. Moreover, the rocks differ much in different regions.

"The Coal beds are additional layers in the series, interstratified with the shales, sandstones, conglomerates, and limestones. But they are thin, compared with the accumulation of rock-strata. The Coal measures contain, generally, 50 feet or more of beds of rock to *one foot* of coal.

"Iron-ore beds also occur, making other thin layers in the series, and rendering the Coal regions the best iron regions of the globe.

"The following section is an example of the alternations (beginning below):

1.	Sandstone and conglomerate beds	120 feet.
2.	COAL	6 "
3.	Fine-grained shaly sandstone	50 "
4.	*Siliceous iron-ore*	$1\frac{1}{2}$ "
5.	Argillaceous sandstone	75 "
6.	COAL, upper 4 feet shale, with fossil plants, and below a thin clayey layer	7 "
7.	Sandstone	80 "
8.	*Iron-ore*	1 "
9.	Argillaceous shale	80 "
10.	LIMESTONE (oolitic), containing *Producti*, *Crinoids*, etc.	11 "
11.	*Iron-ore*, with many fossil shells	3 "
12.	Coarse sandstone, containing trunks of trees	25 "
13.	COAL, lying on 1 foot slaty shale, with fossil plants	5 "
14.	Coarse sandstone	12 "

"The alternations are thus various, and may follow any order. The shales, sandstones, conglomerates and limestones resemble the corresponding rocks of other periods, and *they are distinguished as belonging to the Coal measures only by the fossil plants or animal relics they may contain.* Disastrous errors are often made when this rule is not regarded.

"The beds, even when thick, whether of coal or any of the rocks mentioned, have, in some districts, a limited lateral extent; yet, in this respect the Coal measures differ little from earlier formations. Some of the larger beds of coal are supposed to spread continuously over many thousand square miles of area.

"In connection with the Coal measures of Rhode Island there are extensive beds of quartzose conglomerate, which outcrops at Newport and elsewhere, and form a bold feature in the landscape at "Purgatory," $2\frac{1}{2}$ miles east of Newport. They occur, also, in Massachusetts, between this region and Boston, showing well about Roxbury. The exact position of the beds in the series is not known, as the rocks have undergone great disturbance, and in some places so much metamorphism that the cementing material is a talcose schist. At Taunton, Massachusetts, its pebbles have occasionally been found to contain Lingulæ of the Potsdam sandstone (*Lingula prima*), proving that they are pebbles of this Primordial rock; but whence derived is unknown.

"Besides the rocks mentioned, a buhrstone occurs in beds several feet thick, in Ohio. It is a cellular flinty, siliceous rock, valued highly for millstones.

"The limestones are more extensive in the Coal measures of the Mississippi basin than in those of Pennsylvania and Virginia; while, on the contrary, conglomerates are much less common in the West. This accords with the fact, learned from the earlier ages, that the Appalachian region is noted for its conglomerates and sandstones, and the Interior basin for limestones.

"In Wayne county, in Western Pennsylvania, there are 80 feet of limestone in 250 feet of Coal measures; and near Wheeling, on the Ohio, twice this thickness of limestone. In Missouri, there are 150 feet or more of the former to 650 of the latter. In the lower 150 feet of the Missouri section, there are, however, but 8 feet of the limstone, and in 900 feet of the Lower Carboniferous, in Western Kentucky, only 10 feet. The limestones included among the strata appear often to have a limited lateral range, instead of the uniformity over extended areas common in earlier periods.

"The rock underlying a coal-bed may be of either of the kinds mentioned; but, usually, it is a clayey layer (or bed of finer clay), which is called the *under-clay*. This under-clay generally contains fossil plants, and especially the roots of Carboniferous plants called *Stigmariæ*, and it is regarded (as first shown by Logan) as the old dirt-bed in which the plants grew that commenced to form the coal-bed. In some cases, trunks of trees rise from it, penetrating the coal-layer and rock above it.

"The Nova Scotia Coal region abounds in erect trunks, standing on their old dirt-beds. Each of the 76 coal seams at the Joggins has its darker clayey layer, or dirt-bed, beneath. In 15 of them, there is only a trace of coal; but these, as well as the rest, contain remains of roots (*Stigmariæ*), and often support still the old stumps. (Dawson).

"The rock capping a coal-bed may be of any kind, for the rocks are the result of whatever circumstances succeeded; but it is common to find great numbers of fossil plants and fragments of trees in the first stratum.

"The shaly beds often contain the ancient ferns spread out between the layers with all the perfection they would have in an herbarium, and so abundantly that, however thin the shale be split, it opens to view new impressions of plants. In the sandstone layers, broken trunks of trees sometimes lie scattered through the beds. Some of the logs in the Ohio Coal measures, described by Dr. Hildreth, are 50 or 60 feet long and 3 feet in diameter.

"The thickness of the coal-beds at times hardly exceeds that of paper, and again is from 30 to 40 feet. The beds also vary in purity, from coal with but 1 per cent. of earthly matter, to dark-colored shales, with only a trace of coal. The thickness is seldom over 8 feet, and the impurities ordinarily constitute from 7 to 15 per cent.

"The Pittsburg seam, at Pittsburg, Pennsylvania, is 8 feet thick. It borders the Monongahela for a long distance, the black horizontal band being a conspicuous object in the high shores. It may be traced, according to Rogers, into Virginia and Ohio, over an erea at least 225 miles by 100; and even into Kentucky, according to Lesquereux. But it varies in thickness, being 12 to 14 feet in the Cumberland basin, 6 feet at Wheeling, 5 at Athens, Ohio, and on the Great Kanawha; farther south, at the Guyandotte, 2 to 3 feet

"The 'Mammoth Vein,' as it is called, which is exposed to view at Wilkesbarre, Pennsylvania, is 29½ feet thick. It is nearly pure throughout, although there are some black shaly layers 1 to 12 inches thick. The same great bed is worked at Carbondale, Beaver Meadows, Mauch Chunk, Tamaqua, Minersville, Shamokin, etc.

"At Pictou, in Nova Scotia, one of the coal-beds has the extraordinary thickness of 37½ feet and a second 22½ feet.

"2. *Structure of the Coal.*—A bed of coal, even when purest, consists of distinct layers. The layers are not usually separable, unless the coal is quite impure from the presence of clay; but they are still distinct in alternating shades of black, and may be seen in almost any hand specimen of the hardest anthracite, forming a delicate, though faint, banding of the coal.

"In much of the bituminous coal of the Mississippi basin, a cross-fracture shows it to be made up of alternate laminæ of black, shining, compact bituminous coal, and a soft, pulverulent carbonaceous matter, much like common charcoal.

"The coal itself varies much in character. In some regions, as in the Schuylkill (at Pottsville, Mauch Chunk, etc.) and Wilkesbarre coal-fields, at Peak Mountain, in Virginia, and in Rhode Island, it is of a kind called *Anthracite*, which is non-bituminous, and burns with very little bluish flame. At Pittsburgh, and through nearly all the Appalachian coal-field, and in the other coal areas of North America, it is *Bituminous* coal, which burns readily with a bright-yellow flame.

"The bituminous coal is either of the ordinary brittle kind, breaking into lustrous angular pieces, or the compact *Cannel coal*, distinguished by its firmness, slight lustre, conchoidal fracture, and the absence of any laminated structure. Cannel coal often graduates into ordinary bituminous coal.

"In many places, there are vegetable remains in the coal itself, such as impressions of the stems of trees, or leaves, or charcoal-like fragments, which, in texture, resemble charcoal from modern wood.

"Even the solid anthracite has been made to divulge its vegetable tissues. On examining a piece partly burnt, Professor Bailey found that it was made up of carbonized vegetable fibres.

"*Pyrites* (sulphuret of iron) is sometimes disseminated through the coal-beds in nodules or seams, to the serious injury of the coal. Such coal crumbles down on exposure to the air, and gives forth sulphur fumes when burnt. Even the best of mineral coal contains traces of pyrites: and to this is owing the sulphur smell ordinarily perceived from coal fires.

"3. *Iron-ores.*—The iron-ore beds are usually from a few inches to 3 or 4 feet in thickness. They contain the ore in concretionary masses or plates of a stony aspect. The most common but not most valuable kind has a grayish-blue and drab color on a fresh surface of fracture, and differs from limestone in being

unusually heavy: this ore, called *clay ironstone*, is an impure spathic iron or *chalybite*. Another variety of *ironstone* is an impure *hematite*, affording a red powder. Still another kind is an impure *limonite*, having a reddish-brown or yellowish-brown color, and affording a brownish-yellow powder: beds of this variety are few, but widely extended, thick and valuable.

"4. *Upper and Lower Coal Measures.*—The Coal measures are sometimes divided into the Upper and Lower Coal measures. The most convenient division is above the 'Mammoth bed' of Pennsylvania, as there is a marked change in the flora from this point. It has been proposed to make the Mahoning sandstone the dividing bed, above the Upper Freeport coal-bed, which is the third above the so-called Mammoth bed in the Pennsylvania series. Another great sandstone stratum, called the Anvil Rock, occurs in Kentucky, above the twelfth Coal-bed in the Kentucky series; and this has also been made a dividing stratum in the measures. There is nothing in the fossils that renders the subdivision at these places of geological importance. (Lesquereux.)

"The great Anthracite region of Pennsylvania is largely Lower Carboniferous. The Upper Carboniferous is present there (at Pottsville, Shamokin and Wilkesbarre) up to the top of the Pittsburg group (Lesley); but the rest does not extend so far eastward. The greatest development of the lower coal was in Pennsylvania; and of the upper, in the States farther west. The highest beds in the series appear to occur west of the Mississippi, in Kansas, where they merge into the Permian. There are, however, according to McKinley, 3,000 feet of barren Coal measures above the level of the Pittsburg coal, in the southwest corner of Pennsylvania and the adjoining part of Virginia, and it is not certain how far upward they may reach in the series.

"5. *Equivalency of the Appalachian and Illinois Coal Measures.*—There is great difficulty in arriving at safe conclusions as to the equivalency of the beds in the different coal basins, because the beds of rock as well as of coal—even those that are the thickest—vary much at comparatively short distances over the country. Moreover, as the basins are wholly disconnected, there is no chance to trace even a single stratum from one to another. It is often assumed that the Appalachian and Illinois beds were once united, and were afterwards divided by the uplift of the Silurian about Cincinnati, and extensive denudation accompanying it. But it has been shown that this uplift probably antedates long the Carboniferous Age; and, if this were so, the connection in those latitudes is impossible. It is evident, therefore, that only the most general conclusion on the subject of equivalency can be accepted as established facts. The principal investigations on this subject are those of Lesquereux, who has brought to it a thorough knowledge of the coal plants.

"The Coal measures of Pennsylvania and the States west include twelve to eighteen distinct workable coal-beds, besides thinner seams, the number varying in different regions from certain beds being comparatively local. In this series there are two beds that have special prominence on account of their thickness and the wide range they are believed to have.

"There are, *first* the *Mammoth Anthracite vein* of Pennsylvania, which is the second or third from the bottom, not far from the Millstone grit.

"*Second*, the *Great Pittsburg bed*, the seventh or eighth above the Mammoth vein.

"The following are the equivalents of the beds, according to Lesquereux:

"(1.) *Mammoth bed* (Second workable Pennsylvania bed).—The bed at Leonards, above Kittaning, Pennsylvania ($3\frac{1}{2}$ feet thick), etc.; Mahoning Valley, Cuyahoga Falls, Chippewa, etc., Ohio; the Kanawha Salines; the Breckinridge Cannel Coal and other mines in Kentucky, the first (or second) Kentucky bed; the lower coal on the Wabash, Indiana; Morriss, etc.; Illinois.

"(2.) *Pittsburg bed* (Eighth Pennsylvania bed).—Bed at Wheeling; the *Well* coal, at Mulford's in Western Kentucky, the eleventh Kentucky bed.

"The *Gate and Salem beds* correspond to the *Upper Freeport* (or fifth bed Western Pennsylvania); *Pomeroy* coal, Ohio, situated below the Mahoning sandstone; the *Curlew* coal, of Curlew Hill, Kentucky, or the fourth Kentucky bed.

"In Kentucky, fifteen or twenty distinct coal-beds exist. The eleventh is

supposed to correspond to the Pittsburg bed, and the others are above it. Above the twelfth, there is the massive sandstone, 40 to 50 feet thick, called, the *Anvil Rock*, from the form of two masses of it in Southwestern Kentucky. Six or seven coal-beds occur above the Anvil Rock, in about 500 feet of rock; but they are very thin; the whole amount of coal in this thickness is about 5 feet. (D. D. Owen). The thickness of rock in the Coal measures below the top of the Anvil Rock is about 1000 feet, and of the included coal-beds about 40 feet; making, in all, for the western Coal measures of Kentucky, a thickness of 1500 feet, in which are 45 feet of coal.

"6. *Sections of the Coal Measures.*—In Western Pennsylvania, the western Coal measures, to the top of the Upper Freeport Coal, inclusive, consist, according to Lesley, of the following beds. (Manual of Coal and Topography, by J. P. Lesley, 12mo. 1856. Philadelphia: Lippincott & Co.) The numbering of Lesley by the letters of the alphabet is added; and also that by Lesquereux (the latter in parentheses), as made out from a supposed parallelism between the Kentucky and Pennsylvania beds:

		FEET.
	Millstone Grit	?
1.	COAL No. A, with 4 feet of shale [1 A]	6
2.	Shale and mud-rock	40
3.	COAL No. B [1 B]. (Equivalent of Mammoth bed)	3–5
4.	Shale, with some sandstone and iron-ore	20–40
5.	FOSSILIFEROUS LIMESTONE	10–20
6.	Buhrstone and iron-ore	1–1½
7.	Shale	25
8.	COAL No. C. The Kittaning Cannel (equivalent of the Cannel of Peytona, Virginia, and Darlington, Pennsylvania). [2]	3½
9.	Shale—soft, containing two beds of coal 1 to 2½ feet thick	75–100
10.	Sandstone	70
11.	Lower Freeport COAL bed No. D [3]	2–4
12.	Slaty sandstone and shale	50
13.	Limestone	6–8
14.	Upper Freeport COAL, No E of Lesley [4]	6
15.	Shales	50

"The *Upper Coal measures* are continued in Western Pennsylvania, to the Pittsburg coal, inclusive, as follows:

		FEET.
1.	MAHONING SANDSTONE	75
2.	COAL No. F [5]	1
3.	Shale; thickness considerable	?
4.	Shaly sandstone	30
5.	Red and blue calcareous marls	20?
6.	COAL No. G [6]	1
7.	Limestone, fossiliferous	2
8.	Slates and shales	100
9.	Gray, clayey sandstone	70
10.	Red marl	10
11.	Shale and slaty sandstone	10
12.	Limestone, non-fossiliferous	3
13.	Shales	32
14.	Limestone	2
15.	Red and yellow shale	12
16.	Limestone	4
17.	Shale and sand	30
18.	Iron-ore (spathic)	25
19.	Limestone	1–1½
20.	Pittsburg COAL, No. H of Lesley [11]	8–9

"The upper part of the *Upper Coal measures* (above the Pittsburg bed) in Western Pennsylvania (Waynesburg, Greene County), according to Lesley, includes, commencing below:

	FEET.
1. Shale, brown, ferruginous and sandy	30
2. Sandstone, gray and slaty	25
3. Shale, yellow and brown	20
4. Limestone—the Great Limestone south of Pittsburg (including two COAL beds 2½ feet and 1 foot)	70
5. Shale and sandstone	17
6. Limestone	1
7. Shale and sandstone	40
8. COAL	6
9. Shale, brown and yellow	10
10. Sandstone, coarse, brown	35
11. Shale	7
12. COAL	1½
13. Limestone 4 feet, shale 4, limestone 4, shale 3	15
14. Shale 10 feet, sandstone 20, shale 10	40
15. COAL	1
16. Sandstone (at Waynesburg), with 4 feet of shale	24

"Sections of the strata of Kentucky, Missouri, Ohio and Michigan will be found in the Geological Reports on those States, and others of Nova Scotia, in Dawson's Acadian Geology, and the Quarterly Journal of the Geological Society, 1854, page 60. Mr. Lesquereux has published a memoir on the equivalency of the coal-beds of the United States in the Geological Report of Kentucky.

"The relations of the sandstones, limestones, and shales that alternate with the coal-beds over the wide region stretching from the Appalachians west, are but partially understood. Although these strata seem to be generally limited in range, there is still an equivalency to be ascertained for the whole succession. The rocks, as in other ages, are consecutive records of the events of the period; and, until fully elucidated, the history of the American Carboniferous era will remain imperfectly known."

Above this Paleozoic Time, and these Carboniferous Ages, the Mesozoic Time, or Reptilian Age, follows, embracing the Triassic, Jurassic and Cretaceous Periods, which are respectively composed of the Trias, Lias, Oolite and Wealden; and the Greensand, Lower Chalk and Upper Chalk, with Flint formations: and, lastly, the Cenozoic Time, or Mammalian Age, with its Tertiary and Post-Tertiary Periods of Eocene, Miocene and Pliocene. The Post-Tertiary formations, as before stated, should be avoided by miners.

It will be interesting to notice the succession of deposits above the first Azoic secondary primitives' hardened surface, which will be much facilitated by referring to Webster's Pictorial Dictionary of 1870, where these strata are illustrated and explained under the word "Geology," page 566. The first formation is that of the peculiar rocks of the Potsdam sandstone, the first Calciferous (limey) sand-rock; then the Chazy, Flag and Bird's-eye limestones; not the Utica shale and Hudson River Group. These were probably formed

during the cooling from the warm to the tepid water periods, by almost entirety chemical precipitation of carbonate of lime, in comparatively quiet and small, but, from condensation, rapidly increasing oceans and seas. Thus (favoring a theory that has been fully described), the ocean water overflowing all the lower lands of the world, was urged with *acceleration* forward by the *moon's attraction*, rounding and sweeping the larger Oneida conglomerate rocks into the hollows and flats. The ocean beds, by straightening, or the mountains by arising, or both in conjunction, must have caused the withdrawal of the water trom the land after this period; so that the *continental barriers* controlled the action of the moon, and re-obtained a mere tidal oscillation and a more tranquil state of the waters. Again, sandstone (the Medina) appears, as a recurring precursor to a new series and recorder of a change of water-level, in which the succeeding Clinton and Niagara groups, Saliferous beds, and Helderberg group were deposited.

This is to be noticed for *first evidence of salt* in the Saliferous beds, which may have been supplied from the formation of chloride of sodium of the oceans, *after the chloride of lime* had been precipitated, or as the water released salt *from a colder solution*, which it had not previously done during the Azoic Time. Again, another changing of the water-level is recorded by the Oriskany sandstone and the Cauda-Galli and Schoharie grits, which received the deposits of the Upper Helderberg limestones, Marcellus shale, Hamilton group, Genesee slate, and the Portage and Chemung groups. Again, the Catskill red sandstone covers the Devonian Age of fishes, and underlies the Sub-carboniferous mountain limestones, which are of great depth, and occupied a whole period for formation. Again is evidenced, by the general Millstone grit formation that preceded the coal deposits, a more extensive action of water than any since that of the Oneida conglomerate. On this Millstone grit the thin layers of the underlying strata of the different, similarly produced, successive coal measures have been deposited.

These more recent throes, or shifts of the earth's surface, have been so varied, in innumerable localities, that a thousand geologists would fail, during the collective labors of

their lives, to fully expose the subject. We may, however, easily perceive that a slight depression of the more extensive ocean beds would cause the waters to recede from the much smaller areas of the lowlands, and that a drop of but a few feet of the mountains would again submerge coal-fields, for a repetition of the process. That such has taken place, repeatedly, is as certain as that at this time it is slowly changing the level of hundreds of miles of the South American continent. In the early times, the crust had not solidified, but to a comparatively slight depth, and consequently, the settlings, or deviations from surface contour, to follow the contracting interior, were more easily accomplished than is the case now with the deeply solidified, settled shell.

It may be doubted if extensive mountains, apart from volcanic action, have at any time really arisen, or increased distance from centre, seeing that their height, as compared with the radius of the earth, is but from two to five miles in 4,000, or less than one part in a thousand; the whole surface has settled much more than this, and the ocean beds by sinking faster than the mountains, the latter, by lagging, only appear to be elevated.

In view of these unmistakable facts—of the several growths and burials of the coal seams, with their similar anterior and posterior strata—it is far more natural to suppose that this *difference of contractional travel, or settling of the surface*, had caused these changes, than the real uplifting of such extensive regions; it appears strange that so little difference existed on a contracting globe of such diameter, as the smallest metal globe shows, on solidification from molten to solid state, a very much greater disparity. The American continent, by lying so directly across the attraction of the moon, must have played a very important part in these formations, as a trifling difference of downward travel of this land, or the adjoining ocean beds, would have flooded the whole of the lowlands of America, as Central America became the flood-gate or barrier of the world's waters. If the lowlands of Europe, Asia and Africa were at the same time submerged, the ocean would follow in uncontrolled, accelerating, circumnavigating sway, in one direction after the moon; and even glaciers would vary their voyages accordingly, over many strangely abraded routes. 4

The Carboniferous, or Coal Age formations, were also created and deposited much faster than we can imagine under existing circumstances. The northern portion was then warmer than the tropics are now, whilst the equatorial zone was too hot for animals or land vegetables.

The waters and the atmosphere held in solution and suspension amazing quantities of lime and carbonic acid, which in a manner forced into life, and fattened, the organisms that flourished in the congenial warmth and continual moisture which overshadowed the alluviums of the steaming earth, and its tepid waters; so that, in proportion to the necessity for its removal, was it as speedily accomplished, and its oxygen released for the ample support of animal life.

The accompanying map of the Coalbrook-dale Coal-field, England, from the surveys and drawings of Marcus W. T. Scott, F. G. S., Mining Engineer, will very fully illustrate the actual present positions, and the varied shifts that have occurred since the growth and original deposit of these extensive coal measures. It exposes, to a remarkable degree, the wonderful commotion that then existed in a country that has settled into complete tranquility during the historical ages, and shows the differences of the consecutive intervening strata, as compared to the American measures.

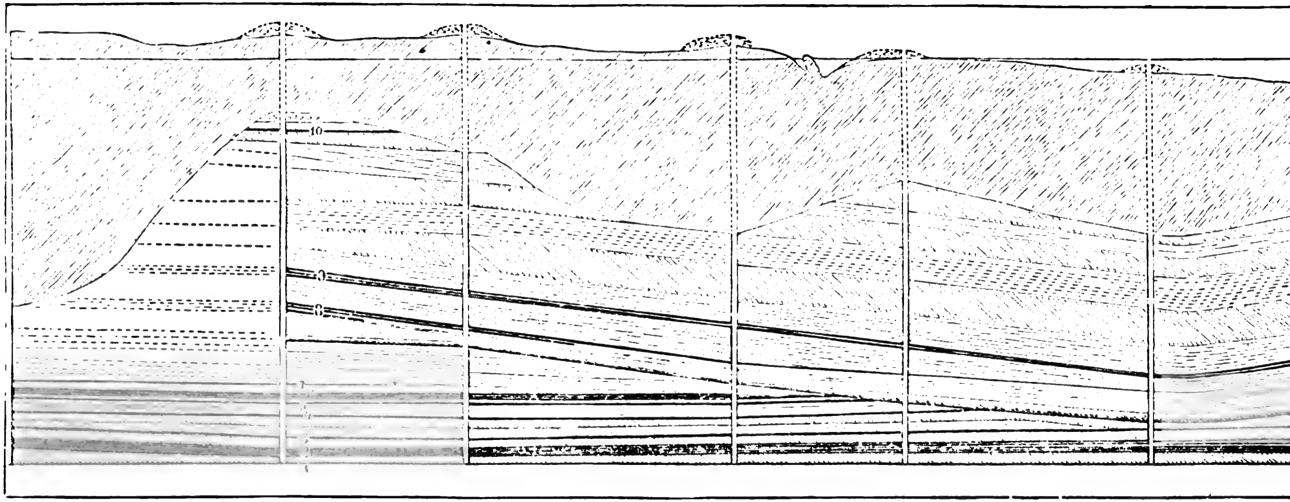
During the subsequent and historical periods, the crust of the Earth had attained a sufficient thickness of cold and solid material to resist this hitherto irresistible side compression, that caused the first innumerable corrugations; then partial volcanic action invaded certain regions, to relieve the interior from pent up gaseous elements, which, forcing out considerable fluid matter, through the few, somewhat distant, and restricted discharge-holes, these mountains arose, as the ejected matter solidified, and built them.

"And God said, let us make man, in our image, after our likeness: and let them have dominion over the fish of the sea, and over the fowl of the air, and over the cattle, and over all the earth, and over every creeping thing that creepeth upon the earth." *Genesis*, chap, I, verse 26

" Thus the heavens and the earth were finished, and all the host of them." *Genesis*, chap. II, verse 1.

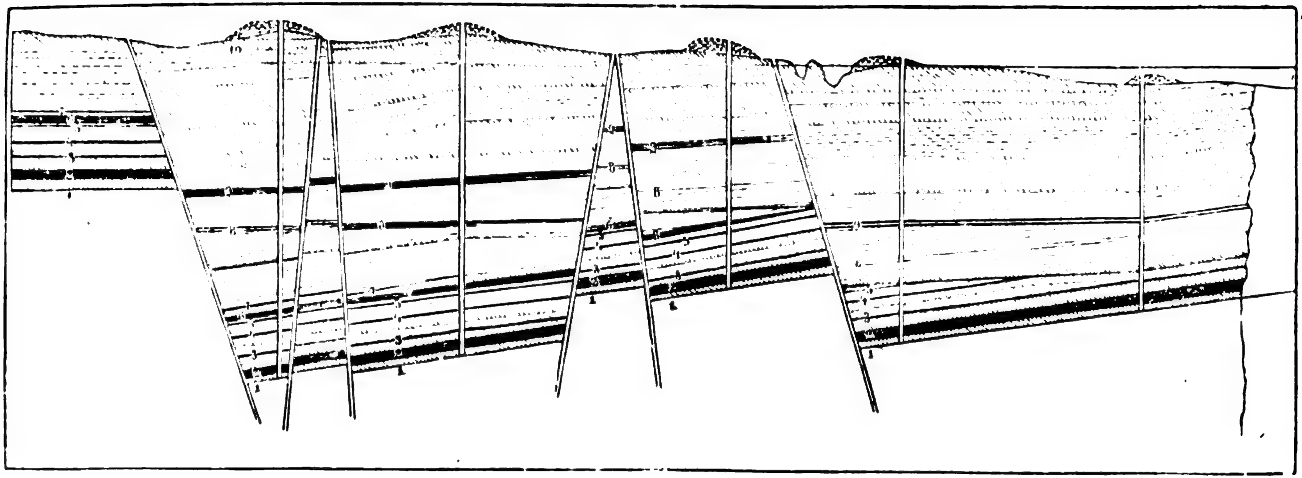
Hypothetical Section of the Strata and Original Surface Contours of the Coalbrook-dale Coal Mines, England.

The numbers show the original positions of the different layers of coal.



1. Little flint Coal; then hard rock. 2. Several seams (the Randle, best, two feet, and clunch Coal); then fire-clay. 3. Stinking Coal; then flint rock and iron stone. 4. Big flint Coal; then white and blue flat iron-stone clods. 5. Yard Coal; then yellow iron-stone clods. 6. Three layers of Coals (the double Coals, the double Coal rock, and half-yard Coals); then a bass and slaty measure. 7. Top Coal; then ball-stone (iron-stone) clod, rock-binds, and clod, "calamincar" (the first persistent stratum above the principal Coal seams), rough rock, and Brickman's measure. 8. Clunches with Coals; then stony binds and rock. 9. Fire-clay clod and Coals; then stinking rock, clunches and rock-binds, thick rock, clunches and clods, and top rock. 10. Coal in the first (left-hand) shaft, with blue and red clod, and clunches, covered by red clay.

Actual or Present Section of the Coalbrook-dale Coal Mines, England.



The numbers show the present corresponding positions of Coal seams, as compared with the Hypothetical Section of their original depositions.

E K Dowsen

CHAPTER IV.

NEW THEORIES FOR EARTHQUAKES.

Many theories have been suggested for the cause of earthquakes, and that of compressed steam—as created by high temperatures, in confined cavities—suddenly finding vent, has been generally most favored.

It is not my business to expose this, or describe the many others; but, as I cannot see that they would create such peculiar motions and effects as we have been but too familiar with, I will offer two new theories, which appear more consistent, for the sudden presence of such powers, the astounding motions created, and terrible effects produced.

FIRST THEORY.—In Chapters I and II, it was argued that a sphere of the size of the earth, would first solidify at the surface, and that many extensive portions of the earth's outer shell are actually arching over immense vaults of subterranean regions, and numerous volcanoes, with their rivers and lakes of lava. Some of these may discharge from continual outlets, whilst others, would occasionally burst forth with amazing strength, at this depth, and hurl immense quantities of lava upwards, to strike the interior of the upper crust with sufficient violence to produce what are termed earthquakes. Now, the Andes and many others of the highest mountains have had their very summits studded with volcanic peaks, and it is well known that some of the more extraordinary throes of high surface volcanoes have discharged thousands of feet above their summits, and covered extensive countries with their diminishing rocks and debris; so that should this deeper and much stronger power be applied under an irregularly shaped *stalactitic* hollow sphere, the central upward motion, so often noticed, would be first felt by the transmission of the blow, in a straight line to all points, as proven by ordinary concussion; whilst the wave would diverge with varying undulations of this comparatively thin, unsupported and more easily shaken

shell. A quick repetition from this same centre would create a similar wave, whilst other craters of the vicinity, would at times burst forth simultaneously, and create the cross or conflicting waves sometimes noticed, when monuments and chimneys are twisted. Or this varied action may be produced by several subterranean peaks bursting forth, urged by the more profound common power, and, from their difference of elevation or speed of discharge, would strike at slightly different times and *slopes*, during such general bombardments of the outer shell or surface crust of the earth.

This would have produced similar effects to the severe shocks, of forty seconds' duration, and those that followed for several days, in 1868, at San Francisco. It does not follow that because some large vaults exist, that all the interior should be thus vacated; for such cannot be so, as the daylight volcanoes do not act together, unless in close proximity. It is probable that these hollows mostly intervene between the subterranean rests of the mountain ranges and the gradually subsiding ocean beds and extensive plains.

This theory possesses the advantages of tangible practical agencies which are known to exist, and conclusions founded upon substantial reasons. Volcanic action, once much more general at the surface than now, has naturally retired with decreasing temperature to its more suitable subterranean regions, to discharge into these vaults, leaving but a few necessary external escapements, in the form of long dormant volcanoes; whilst others still discharge from the solid supporting points of the living mountains that are connected with the deeper interior by separate passages.

The fact of the existence of such hollows is least substantiated; but every thinking man, who has been accustomed to earthquakes, must know that such undulating waves as accompany severe shakes could not be produced on a solid sphere, and that it is simply absurd and contrary to the observations and laws of contraction, even on the small scale with single homogeneous materials, to suppose that the still red-hot interior has ceased to contract because its surface is cold and solid. No man who credits the igneous theory can doubt that a hot interior of nearly 8,000 miles' diameter has contracted during refrigeration, and that, like smaller metallic

globes, the surface becoming cold before the interior, the extent of such cavities would be proportionate to the sizes of the contracting bodies. (See foot note at page 20.)

Although the theory just described may fully account for the frequent strong actions, which recur at certain places, where the volcanic agencies are most concentrated, I am convinced that another principle of action must cause the isolated shakes which are occasionally felt everywhere, in all formations, throughout the world.

SECOND THEORY.—Based on the following axioms.

The surface is colder than the interior.

Difference of temperature cannot exist without corresponding inequality of motion, during general contraction, as produced by refrigeration and gravitation, as described in past chapters.

This unequal speed of shrinkage of sections in contact, must produce great compression, violent jarring, with much friction, and local heat.

In the first, second, and third chapters of this section it was demonstrated, that the gradually cooling globe would first solidify at and near the surface, and that the hotter still plastic and molten interior, in lessening its diameter, would leave this shell to sustain itself, under the enormously powerful action of gravitation. This internal support being thus removed, the rocks of the crust were insufficient to support the prodigious side pressure thus created, and the solid surface crumbled or became, under pressure, again plastic, at the lines of least resistance where the corrugations of mountains and valleys were formed; and the surface, circumference, or area, being thus reduced, the remaining portions then settled down to rest on the interior as before, until a repetition ensued. Now, in modern times, this shell has become so thick that it almost sustains itself, although slight changes are still occurring.

Before entering upon the particular principles of this second theory, you should in addition to the above effects of apparent upheaval and subsidence, produced by contraction and gravitation, fully understand *another resultant motion*, which must inevitably occur just at the moment when the mountains were suddenly forced into shape by the surrounding lateral pressure; which is that of the *equally sudden move-*

ment of the unchanged *adjacent country and its mountains, towards* the aggregated and thickened compressed mass of *new mountains* thus formed. The total extent of this *circumferential* motion will also be more than thrice that of the *diametrical* contraction of the interior.

With these facts before us, we will suppose that at a suitable depth, where the rock has also solidified, an inner hollow globe is now undergoing similar changes from contraction, etc., and forming subterranean mountains ; so that when a mountain range is thus suddenly shaped by this astounding crushing power it would *bump against the outer shell*, whilst the adjoining side ranges, by advancing towards the crushed plastic mass, would also rub violently against its irregular stalactitic interior and thus produce the peculiar varieties of earthquakes ; shock, sway, and wave.

Another consequent effect of this pressure will be, to create and sustain volcanic heat, and cause the metamorphism of rocks.

All volcanoes discharge more or less steam, and it has been therefore supposed that proximity to water is a necessity of their existence, but the very *rims* of the oceanic basins where they generally lie, have been, and are being formed, by that same compression which creates and sustains their heat, whilst the hydrogen of this water may have proceeded from the interior of the Earth, where under sufficient pressure it may lie in liquid or solid state until it is by some means removed, when it might create even the *ejective power*, whilst the actual water—derived just like that of the ocean itself from this internal source—was but the *product of combustion* with atmospheric oxygen, at or near the orifice.

Since my first edition was published, where this was alluded to, the spectrum has proven that *explosions* of burning hydrogen, are of frequent occurrence in the sun, where its peculiarly colored flame is seen to shoot *out and upwards* in vast volumes for scores of thousands of miles ; which is a perfect demonstration, that hydrogen must be a heavy liquid or solid under suitable conditions ; for when freed it becomes the lightest of all the known gases, and could not in such a state, *descend*, so as to burst, in this striking manner, from *beneath* the burning mass of the sun.

CHAPTER V.

FORMATION OF "TRUE FISSURE VEINS" IN THE AZOIC AND METAMORPHOSED PALEOZOIC ROCKS—OF CONVERGING OR WEDGE VEINS IN THE CONVEXED UPPER SECTIONS OF UPHEAVED BED-ROCK—OF VEINS THAT ARE MORE OR LESS CONFORMABLE TO THE GENERAL CLEAVAGE OF THE TILTED STRATUM, IN THE SEAMS OF WHICH, GANGUE, MINERALS, AND METALS, HAVE BEEN DEPOSITED—OF VEINS THAT INTERVENE AND SEPARATE DIFFERENT STRATA, AS GRANITE AND SLATE, OR SLATE AND LIMESTONE, ETC.—OF GASH VEINS—OF CROSS-COURSES—OF SLIDES—OF DIKES—OF CARBONAS, BONANZAS, POCKETS, AND FLOORS—OF IRREGULAR SUBLIMATIONS, ALLUVIAL DISTRIBUTIONS, AND SEDIMENTARY DEPOSITS.

TRUE FISSURE VEINS.

The formation of fissure veins is as much exposed to speculative theories as earthquakes, and even more difficult for solution. Although it appears probable that many of the true fissures were first formed by the repeated violent concussions called earthquakes, yet so many stumbling-blocks obstruct the path of argument, that it appears impossible to travel from this cause to the various effects produced, in the extensive systems of mineral veins.

It is easy to account for one fissure being formed in front of a hill or mountain, in a line of least resistance, or even on the more regular plain, which has been thus accomplished in our day and locality; but when the ramifications of a very numerous system of veins are exposed before us, with their

ever varying sizes, directions, dips, angles and spurs, intersections and crossings, both lineally and vertically, as they lie in strata, it is almost impossible to fully comprehend this labyrinth of wondrous work.

It is probable, that as so many of the systems of mineral veins are situated in low fronts of mountains and hills, that such mountains, by continuing downward to the interior, as previously described, may, by *forming the solid margin* to the subterranean hollows under the flat portions of the surface, create fissures at this hinging point, during the action of waves produced by earthquakes, as they approach and fracture on the mountain shore.

Again, it may be that similar waves, proceeding from a more oblique centre, may have produced the diagonal veins and cross-courses; whilst the settling of the mountain during these shakes, from its superior weight, created the slides; and the direct upheaval of igneous power, exerted immediately below, caused the fracture of the larger dikes, and filled them with igneous matter.

ANOTHER VIEW OF THE CASE,

Suggested by the presence of these igneous dikes, metamorphism, and the numerous veins, with the crumpled and crushed appearance of the rock of such sections, may be illustrated by supposing that a second heating of the cold and solid crust occurred, as caused by enormous lateral pressure of the earth's surface, just at these places, or from the near approach towards partial invasion of this particular portion of the surface by subterranean heat; for as the expansion caused by heat is unlimited, and all side extension was prevented by surrounding rock, the warmed portion would occupy the same space as before, and would shrink on cooling, in proportion to its extent and degree of warmth, to form the various fissures, as large or larger below as above, and account for other differences in the appearance and crystallization of rocks, peculiar to such districts.

In this proposed theory, which I believe is new, the after expansion would be the ruling power in the formation of fissures; and, consequently, at the time each vein was fractured, the line of contraction would be at or about right-angles

therewith, and the variation of the position or extent of this second heat would, by causing different lines of expansion and contraction, form fissures that partook of correspondingly different bearings to those previously created. Earthquakes would then but assist and modify these results.

This principle of the *second warming* of certain *spots* of the hitherto *simultaneously cooling* globe, has also been a leading power in upheaving whole districts of mounds and mountains in volcanic regions; and, in such positions, the contractions have also produced veins during the second local and more speedy refrigeration; but the rock is of the wrong kind, or the base mineral elements are too much scattered and sealed by fusion, to be present in the veins, for the subsequent precipitations from the collecting solvents, as in the more ancient metalliferous strata.

Veins have been occasionally fractured at the line of least resistance, by earthquakes, and opened by recedence of the outlying flat from a mountain's frontage; at other times, by fracture and subsequent divergence of the walls, as the rock was convexed during the uplifting of hills over igneous action, and by independent fractures which may extend for miles. But such formations, either from want of age or from traversing modern strata, have seldom produced profitable quantities of the base minerals.

CONFORMABLE, CONVERGING, WEDGE, OR "SEGREGATED" VEINS.

These very numerous and universally distributed veins lie between the divisions of stratified rocks, as gneiss granite, clay-slate, etc. They are seldom of great length or size, and are always unreliable, for, the wedge like space between the walls of the cleavage of the upturned stratum, must, from necessity, diminish by becoming flatter and closer in depth.

In gold and silver regions, with other conditions, they contain gold and silver, but are generally worked at a loss, when *strictly conforming* with the *divisions* of the stratum.

The largest and most profitable veins are those which have been formed by more extensive contraction, acting in a direction at right-angles to the general run of the granitic mountain, or spur, (that caused the tilting of the slate,) which may have been suddenly consummated by the immediate

assistance of earthquakes; such veins are, also, conformable to the cleavage of the stratum for short, suitable distances, but take a separate path in those more general sections that deviate in direction or dip from the lines of least resistance at the moment of fracture. That is, the plane of the fracture caused by contraction and shake, although frequently swerved by cleavage, would invariably return to its own original course when more direct, which *would always be the richer paying* section of the vein, because it partook more of the principle of true fissure, and not only was enriched by the numerous feedings of several of the divisions of the stratum, during its diagonal passage, but it consequently held its size and quality for greater length, and in depth. Too much consequence cannot be attached to these facts by the gold and silver quartz miner; for even here the advantages derived from deep and extensive fracture, which resemble the true fissure system, are most readily seen by comparison.

Another example of converging or wedge veins would be when igneous action uplifts a small district, so that an originally flat piece of country becomes convexed at the surface, when consequent fractures would necessarily form diverging walls from the centre of action, which space being filled by sublimation of the oxides of base minerals, and the deposition of subsequent compounds, would form veins, either with or across the stratification, according to the position of the original deposit of bed-rock. Here both the actions of divergent separation, and the subsequent contraction of the warm district, were in power. In such positions, the depth and size will vary with the distance from centre of motion. A remarkable illustration of this may be seen in the small foot-hillocks fronting the Trinity Mountains, of the Arabia District, near Oreana, Humboldt county, in the State of Nevada, where there is quite a system of such veins, which contain considerable quantities of ferruginous argentiferous lead and antimony.

OF INTERVENING VEINS BETWEEN DIFFERENT STRATA.

It frequently happens that one stratum, or dike, or broad channel of rock, recedes very gradually, by force of contraction or settling of the adjoining plain, from another, and the

intervening space, in old formations, is afterwards filled with quartzose or other gangue, whilst the mineral components are obtained from the adjoining strata, and deposited by infiltration; or, when over igneous positions, by intrusive action and sublimation modified by after solvents and precipitants.

In "true fissure vein" districts, such are more generally despised than wrought; in fact, the more effective, deep contractive action, that produced the true fissure veins, has, by thus using up this power, almost entirely prevented these formations, which are more generally present where other veins either run nearly at right-angles, are scarce, far removed, or entirely absent. In some instances, where a compact primitive rock mountain slopes at a steep, regular declivity, and is fronted by a broad belt of porous metamorphosed rock, a partial decomposition of the rock ensues, when probably the released alkali, being carried with the water to the more solid face of the mountain, meets and precipitates the minerals upon this water-tight foot wall.

Silver and gold have been sometimes found in such positions, in very profitable quantities; but, for reasons that will be explained in chapters devoted to these purposes, although the vein will attain considerable size, it will possess no upper wall, the foot wall will not be well or regularly defined, and it will not produce sufficient quantities of base minerals to pay profits, to large mining companies.

GASH VEINS.

This class of veins may be found in all sedimentary deposits, and may be compared to the ordinary cracks that are to be seen in dried or contracted mud-beds, which over-lie another different formation. They are merely caused by directly local contraction of the single stratum, as it dries or hardens by natural warmth of the atmosphere, or is baked into rock by underlying igneous influence.

Although each successive layer of particular stratum may be separately fissured, the veins never continue (unless by chance) from one stratum into the other, or extend for any great distance; so that profits should be expected more from the numbers of such than from a single limited vein. Thin floors, or horizontal seams of mineral, generally prevail

in the divisions of the stratum of such formations, which frequently increase the supply.

CROSS-COURSES

Are transversely fractured fissures, of more recent origin than the regular veins, on which the previously formed veins necessarily slide, to accommodate the varied contraction of the country that contains the whole system of veins, cross-courses and slides. They are generally advantageous feeders for the copper and tin deposits of regular veins, though, within themselves, invariably poor for these minerals.

Near the copper and tin veins of Cornwall and Devonshire, in some of these cross-veins, or courses, when more than one mile from the granite and sections still further away, in suitable stratum, the best lead mines are situated.

SLIDES

Are still more recent fractures, very uniform, and of smaller size than "cross-courses." They contain more clay, and less quartz and mineral, are not so extensive, and dip less.

DIKES

Are different to all these; generally much larger, composed of a yellow or blue-colored feldspathic finely crystallized igneous rock. They have in some way mineralized the veins, but now contain little or none in themselves.

CARBONAS, BONANZAS, POCKETS, FLOORS, AND DEPOSITS.

Carbona is a word much used in the west of Cornwall, for pockets of tin ore that are found on either side of the lodes in the adjacent country rock, which are connected with the otherwise mineralized veins by very small strings, vughs, or branches, which enlarge suddenly to form the carbonas. The expression is confined to such positions as offshoots from an otherwise generally mineralized vein, and to the more compact bodies, and not to branches, isolated pockets, or separate deposits.

Although such have been found all over Cornwall, they are more particularly displayed in frequency, size, and riches, in the districts of St. Ives, and Lelant; where the otherwise moderate ordinary profits derived from the lodes are some-

times increased to an extraordinary degree by these carbonas.

These districts may be considered one, as they lie connectedly on the northern, eastern, and southern slopes, of a granitic crescent, formed by the several small mounds called Rosewall, Knill's Steeple, Trencrom, and Trink Hills.

At the eastern end of Rosewall Hill, the Rosewall Hill Mine is situated, and these veins continue east into the St. Ives Consols mine, which has yielded large profits from the principal lode, as frequently assisted by numerous ramifications of rich network veins, and these carbonas. One of the latter, happening to be under the house of a poor man, the dues (of probably but one-eighteenth of the total value) placed him suddenly in luxurious circumstances. These veins then pass through Wheal Trenwith into the sea.

The next celebrated carbona mine is the Wheal Providence, on a parallel lode, situated about one mile south from this, which runs from Knill's Hill into the sea; their profits and market value having been repeatedly influenced by similar discoveries. The flanks of these hills have been much broken or crumbled, and the rock that adjoins the veins is often found either decomposed or decomposing.

The *Bonanzas*, of Mexico, have a similar but more extended meaning, as they apply to all positions in stratum, both when attached and when detached from veins.

Pockets lack veinous appearance and continuance, are of irregular shape, and occupy all positions.

Floors differ from these by filling the spaces left between horizontal faces of stratum, or strata, and are often very extensive.

Deposits are such as must have been concentrated by the sublimation, alluvial water-washing, infiltration, or precipitation of considerable quantities of minerals, on a certain spot, or into a suitable receptacle of bed-rock.

Those of sublimation would apply to the volatile and condensable minerals, as the deposit of cinnabar of the New Almaden Quicksilver Mines, and to the sublimations of lead and antimony at the Montezuma Mine, already described.

The alluvial deposits are the oxide of tin, the gold of the placer diggings, platinum, etc.

Those of infiltration, and precipitation, will include all such as must, from the peculiarity of their bed-rock, have been thus deposited.

The sedimental deposits will be generally found in horizontal layers, underlying, and more or less conformable to, the coal measures.

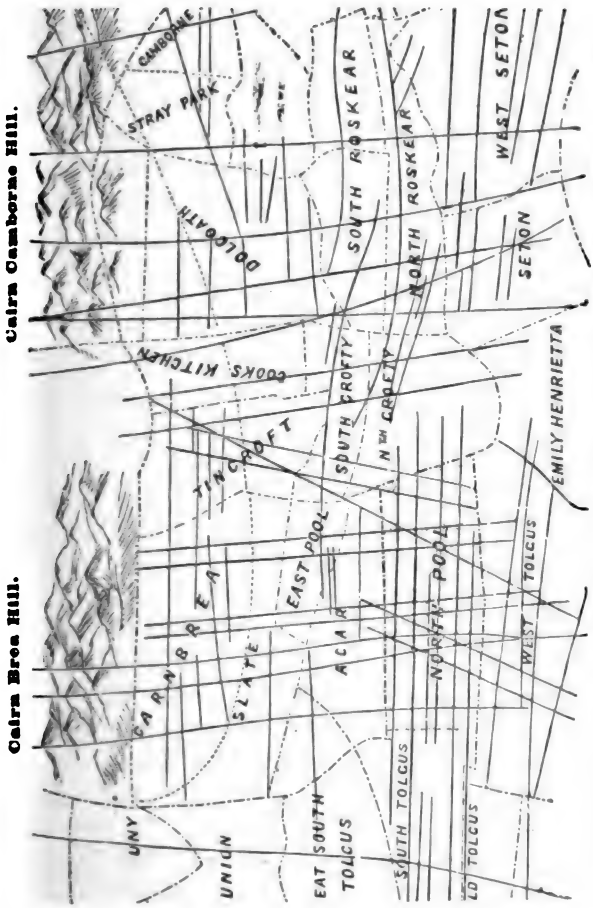
There is still another class of veins which must not be forgotten, as they are equally well defined, and crop but too boldly, as *embossed burlesques of all serious consideration of this subject;* reminding us that man's comprehension, of even the inanimate creations of the Supreme Architect of the Universe, is extremely limited.

I allude to the veins, angles, and spurs; deflections, comparative bearings, and dips; junctions, intersections, and variations; contractions, enlargements, and pockets; cross-courses, elvans, dikes, and slides; with every variety of heave, shift, or slide, which are also present in those wonderful miniatures of the larger systems of veins, so frequently seen in the small water-washed bowlders taken from the pebbled shores of suitable formations of all ages of rock, as well as similar miniatures in small stones extracted *from* veins. These could not have been formed by any means yet suggested, and it must be, therefore, admitted that the law is utterly unknown that governs the creation of such diminished *fac similes* of lodes, cross-courses, dikes, and slides.

Silicic acid, and all the components of the other gangue stones, appear to be urged by some subtle power to aggregate and arrange themselves in such ramifications with other bed-rock matter, and on this small scale, to a much more general extent than in true fissure veins; and the question arises, whether or not the principle extends throughout all the intermediate stages from the small to the large scale?

If contraction of the surface is the fabricator of small and large fissures, why are the intermediate stages not thus interlaced by fissures in similar rock? Again, why should the true fissure districts alone exhibit this phenomenon on the large scale, whilst *all kinds of veins* show, more or less, these features in *small stones,* taken from such veins? It is possible that the deep-seated fracturing power peculiar to the true fissure system, by allowing greater freedom for more equal

settlement, may thus arrange its veins to resemble these miniatures in this particular, and that the remaining laws may work differently in small stones of veins and country.



THE VERY RICH SYSTEMS OF COPPER AND TIN LODES, SITUATED BETWEEN THE TOWNS OF CAMBORNE AND REDRUTH, CORNWALL; WHICH LIE IN THE SHALLOW CLAY SLATE FRONTAGE OF THE CAIRN BREA, AND CAIRN CAMBORNE GRANITE HILLS, AND CONTINUE DOWN INTO THE GRANITE, THAT IS THUS SUBMERGED BY THE SLATE.

THIS DISTRICT YIELDS COPPER TO ABOUT 1,000 FEET DEEP, THEN THE COPPER LESSENS, AND TIN IS FOUND IN GREAT ABUNDANCE BELOW. IN OTHER PARTS OF THE COUNTY THIS IS REVERSED.

CHAPTER VI.

THE SUPPOSED ACTIONS AND REACTIONS THAT HAVE BEEN AND ARE CONTINUALLY TAKING PLACE IN MINERAL VEINS, POCKETS, AND DEPOSITS—HOW MINERALS WERE FORMED—HOW GOLD, PLATINUM, AND SIMILAR METALS, WERE FORMED.

In the consideration of these subjects, we had better start from the period when the *base metals*, and even the *precious metals of to-day*, were chloridized or oxidized by *immeasurably long* fusion and refrigeration, in presence of chlorine and oxygen from the atmosphere that surrounded the red-hot surface of the earth, as described in Chapter II. On referring to page 24, Chapter I, it will be seen that nearly half the weight of the "bed-rock" is oxygen, still leaving a surplus in the atmosphere, and that these lighter metals and oxygen formed the entire primitive rock surface of the Earth.*

Thus, everything of a fixed character that existed was an oxidized metal, of low specific gravity. General ignition, and long-continued natural causes, have produced, on this massive scale, precisely what might have been expected from the every-day experience of the chemist; and fire has thus supplied the world with similarly simple compounds—the oxides of all the metals—which were more or less distributed throughout and over the primitive rock formations, thus providing for the more diversified future developments, when general reactions resulted at appropriate times, under suitable conditions of pressure, and consequent temperature.

Another favoring reason for this is, that the useful metals, being all much heavier than those that formed these rocks, could not have reached the surface, unless lightened by union with oxygen into volatilizable states. None of the

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* If the base metals were chloridized, they would, being soluble in fresh and salt water, be subsequently decomposed.

metals that immediately concern the miner (although their affinities for oxygen were equally strong) formed such permanent rocky oxide compounds; so that, being more friable, they were more or less disseminated throughout the rock, or were sublimed into the dense atmosphere that then surrounded the hot surface of the Earth.

These were undoubtedly the simple states of mineralization, when the Earth had cooled down to a low red heat, and the surrounding atmosphere was largely composed of chlorine gas, the vapor of water, the resultant product from the combustion of hydrogen and oxygen, and carbonic acid gas, similarly produced by oxygen and carbon, during the world's fusion. Thus were oxidized even carbon and hydrogen.

The next universal action that transpired was during the period described in the latter part of Chapter II, Section 1, when all the minerals that were soluble would have been dissolved from off the surface by the condensing steam, and conveyed to the hollows, thus separating the soluble from the insoluble bed-rocks.

Some of the minerals that are now insoluble at ordinary temperatures, in water, would have been quite soluble then (at the high temperature that resulted under the extreme pressure described); and others, that resisted the hot waters of the period, would have succumbed to the extremely hot chlorine, or the alkaline solutions that followed, and were held therein until a lower temperature favored their precipitation, or union with other elements, at places where precipitants happened to be located.

It appears probable that, in this universal oxidation of the metals, the oxide of sodium formed the greater part of soluble surface scum over the dry Earth, and chlorine gas would be in considerable abundance in the mixed atmosphere, as liquid chlorine under pressure, or form, by hot explosive union with hydrogen, hydro-chloric acid, that would, in either case, be collected by the falling rain into oceans of chlorinated water, in which many of the minerals would be dissolved; some would be precipitated by the soda, as it was washed from the higher grounds, and formed the chloride of sodium of the ocean and probably the oxygen of air.

Thus, the greater part of the primitive surface would have

been more or less covered with these numerous precipitations of the oxides of the metals, whilst the interior, below the reach of these solvents, would retain the original oxides, as first fused or sublimed. These may have been the ruling powers, because most abundant; but, as all the agents and re-agents of nature that fire created or expelled were present, each acted its part in the general reassociation, more particularly during later and colder periods, after the general reaction of carbonic acid had set in to precipitate from the ocean solutions its chloride of lime into the first purely chemical and inorganic carbonate of lime, secondary rock formations, which thus fixed and recorded the first evidence of the presence of carbon. At about this time, the first magnesian and magnesian lime rocks would also be deposited; then the Azoic calciferous slates and various mixtures, from the disintegration of primitive granite, when the oxide minerals would be more or less simultaneously disseminated throughout these formations, until the liquid agencies ceased to dissolve and convey to the ocean reservoir any considerable amount of mineral waters.

This manner of distribution would deposit the minerals in diminishing quantities, as time passed away, and the later organically and mechanically formed secondary rocks would consequently contain much less than those that were deposited during the hot Azoic, less tranquil time; and such is precisely the case.

Thus, the minerals must have been *first distributed* throughout the rocks *before the fracturing* of the true fissure veins, or formation of the various other receptacles for subsequent aggregations.

HOW MINERALS WERE FORMED IN VEINS, ETC.

It has been clearly shown above that the mineralizing agencies of fire and fluids had not thus far done more than to *oxidize and disperse the material elements,* for *future collection and precipitation* into the suitably small receptacles of veins, pockets, or basins, for man's beneficiation: but to attempt to explain *all* of the next succeeding complications by any single rule, will be as presumptuous as impossible.

To lay down any particularly fixed theory, "Plutonic" or

"Neptunian," "Sublimation" or "Infiltration," for all developments, is monstrously absurd; for it is not only contrary to the known actions and facts of the past and present, but is a chemical impossibility, as the agencies of fire, gases, and liquids, are eternally composing or decomposing; and whilst Time moves, chemical actions will also continue in operation, and change of condition be more the rule than the exception.

Fire, however, generally supplies the raw materials, either directly or indirectly, as just described, and sometimes in part to true fissure veins; as it also aids most remarkably in many instances by warming solutions that dissolve certain minerals, which would be insoluble at lower temperatures; whilst the gases and liquids manipulate to perfect the more complicated *crystalline* forms, found by the miner in all *kinds and ages* of *rock* formations, long after the action of fire had ceased its operations.

For consideration of this subject, we may suppose that a system of true fissure veins had been fractured by secondary contraction, after a spot of the Earth's surface had been metamorphosed, or reheated by the second approach of internal fire, after the manner described in Chapter V, section 1. As there stated, the different parallel, diagonal, and cross veins, dikes, and slides, were not all formed simultaneously; and, consequently, frequent shiftings of portions of the earlier veins on the walls of the later have resulted, which afford many interesting records of past progress, and some very palpable present evidence, that favor the more recent concentration by aqueous solutions, and the still later depositions of the minerals from their respective salts.

It has been thus emphatically proven, on preliminary general grounds, that, although the metallic oxides were first supplied by fire; humid agents must have generally completed the mineral formations; and such is strongly corroborated by the following facts, that are unfolded, by the thoughtful miner, from the metallic mineral veins:

1. If the *veins, pockets, etc.*, were filled by fire with *fused quartz*, the veins must have been then at *full size*, and *all the contraction* of bed-rock that ever did take place must have

then occurred at the *moment of fracture*, which is as absurd as it is untrue.

2. None of the homogeneity or other peculiar appearances of a fused mass has ever been detected in such deposits.

3. If fused, and thus intruded, some overflowings would have protruded, similar to those from lava.

4. Being lighter and more infusible than any of the other elements from volcanic action, it would, because it required greater heat, have been the first, and not the last, to arrive at the surface.

5. It is too purely *the one unmixed oxide of silicium*, to have been fused at this necessarily high temperature, in proximity to other more fusible elements.

6. The minerals contained therein are too unequally disseminated to have been the resultants of fusion, or sublimation.

7. Disconnected pockets, and the various minute ramifications in distant country, bed-rock, stratum, and the miniature veins of pebbles, etc., alluded to in the latter part of Chapter V, could not have been so formed.

8. Vein quartz has a constant specific gravity of 2.8, whilst that from fusion is but about 2.15.

9. Volcanoes never eject pure quartz, or other pure, unmixed elements.

10. Fluor spar (fluate of lime), and heavy spar (sulphate of baryta), with many other volatile compounds, and even water, are often found completely enclosed in quartz, which could not have existed here, no more than in the primitive bed-rocks, if created by fire.

Thus much, and more, may be brought to bear against the general and independent actions of the "Plutonic" and "Sublimation" theories; and, to still further favor those of the "Neptunian" and "Infiltration," the following may be added thereto:

11. We have positive proofs, in the laboratories of Nature and Art, that not only many of the reactions *can be*, but that they *are being* produced by natural humid causes; whilst fire, both in Nature and Art, fails to perform similarly perfected results.

12. Constitutional and mechanically enclosed waters are as

perfectly consistent with the aqueous, as unnatural and impossible by fire.

13. Changes of strata generally effect corresponding variations in the quality or quantity of the minerals, as the veins pass through their respective sections, from the presence or absence of solvents or precipitants. These do not apply favorably to fire.

14. Free passage of waters favor the presence of the minerals.

15. It frequently happens, in the most complicated systems of mineral veins, where several ages of fractures occur, that when a mineralized vein has been "heaved" or shifted sideways by a cross-vein from its original position, by irregular contraction of the country, it is rich in mineral on the one side of the influential crossing, and poor on the other; thus showing that the minerals were deposited by water, long after fire was in action.

16. True fissure vein quartz invariably shows laminations more or less parallel to the walls of the vein, whilst fused quartz does not; which laminations, being probably deposited separately on each wall, as the walls recede by contraction, frequent, more central crystallized cavities are found, that partake of somewhat similar parallelism.

17. It often occurs that separate courses of tin, copper, and iron, are found in the same vein, for some several feet; then the whole becomes more or less intimately disseminated and speckled with each, or a single course of the one, or the other, may be found as the level is continued, intervening frequent barren sections of the vein; all of which appear as natural to the aqueous as unnatural for the more dispersing regular productions of fire.

18. Their constitutional or equivalent forms, although extremely varied, are always exact; and many of their associating elements are unnatural to the chemistry of fire; others are derived from the surface, and a few are even organic.

19. The upward, chimney-like speed of the sublimations of the minerals, from the action of fire, would have effectually prevented the downward access of these necessary elements for the existing combinations in veins, at all depths.

20. They would have been richer for such varieties at

the top, and simply one or two fire compounds at deeper sections.

21. The minerals are often deposited in crystals in the central and last formed quartz cavities, on the previously *perfected quartz crystals.*

22. The walls of veins that, at first fracture, must have *exactly corresponded,* do not retain such shapes now; as in many places the walls, as shown by the irregularity of the width of enclosed quartz, are very unlike, a few feet of distance often exposing expanding cavities, that could not have been formed by any other means than actual dissolution of the solid rocks, probably by hot water in a manner hydrating the silicic acid, and silicates of potash, that are known to compose such.

23. Converging or wedge veins intervening the divisions of secondary stratum, which run to a thin point in depth, *must have been* formed by *aqueous solutions,* and not by fusion; unless the minerals were actually poured in from above, which is too absurd for credence.

24. The pure carbonates of lime, and baryta; the sulphates of lime, and baryta; as well as the fluate of lime matrices of veins, are much more natural to the aqueous than igneous creations.

These facts afford sufficient evidence that the chemistry of fire has not ruled supremely in the formation of the minerals, but merely supplied the crude elemental compounds by general sublimations; as also, at least to some extent, to the hot and compressed aqueous solutions of the deepest sections of mineral veins.

Internal fire has, however, by creating, under the suitably extreme pressure of the water in veins, *sufficient degrees of heat* to render many substances soluble, either alone or assisted by acids or alkalies, that are, under the ordinary circumstances of pressure, and consequent heat, insoluble therein; as quartz (silicic acid), fluor spar (fluate of lime), heavy spar (sulphate of baryta), etc., etc., as well as the mineral elements.

Ever since the time of my being educated in the chemical and mechanical sections of my profession, some thirty-five years since, after I became acquainted with the general laws

of sensible and latent heats, more particularly as they apply to water and its vapor, I have been strongly impressed with the notions (as expressed in Chapter II, Part 1) that highly heated water had much to do with the formations of matrices and minerals in lodes, as well as the modifications of the earlier secondary surface rocks; and that conviction has been strengthened by close observation during long experience.

To render these principles of action and reaction more intelligible, we will suppose that metamorphic action had preceded the time when the veins were formed, and that the belts of country between the fissures had commenced receding (from contraction), to expand the width of the intervening spaces, in which the elements that now form veins were deposited. As these walls separated, surface water would force its way down to the hot interior sections of such fissures, which, at only 1,500 feet deep, would create, from its own weight, a pressure of fifty atmospheres, which, if sufficient heat was also present, would raise the boiling point of pure water to 510.6°, and of water that contained chemical salts to a still higher degree; whilst still deeper sections, under greater pressure and consequent temperature, would attain sufficient heat, not only to dissolve, but to even melt away, many of the metals. Thus, the matrices and metals would, at least, have been readily dissolved into solutions with water alone, and as the solution became more *equalized* from the *deep* to *shallow sections* of the veins, the pressure and heat becoming less, they would, being ruled by such change of condition, again deposit from the colder solution the matrices and minerals accordingly, on the walls of the future vein.

This solvent would collect the minerals from sublimation as well as by infiltration, and deposit them in the shallower sections, conformably with the favoring elements present.

In the general first fusion, as well as in partial volcanic fusions, sulphur and chlorine have been volatilized in considerable quantities; and it is, therefore, probable—nay, imperative—that those notorious elements have sometimes united to the hot water their superior solvent properties, and thus produced, at a less temperature, more shallow solutions and diversified precipitates, from the various causes of *less-*

ening of temperature, dilution of the solution with surface water, and the *decomposition of the silicates of soda*, or *potash*, from the adjoining rocks.

The lessening of temperature, watering of the solution, and the alkalies, have all been more or less subservient to their deposition, but mostly the latter, which, in the laboratory, speedily precipitates aluminum, antimony, bismuth, cadmium, chromium, cobalt, copper, gold, iridium, iron, lead, manganese, mercury, molybdenum, nickel, osmium, palladium, platinum, rhodium, silver, tin, uranium, vanadium, zinc, etc., etc.

Some of these are soluble in excess of these alkalies, whilst others are insoluble, and undergo other more modern changes, until, by some process peculiar to very long-continued natural causes, unparalleled in the speedy reactions of artificial chemistry, they unite with the various elements into more permanently well defined, compact crystals, such as arseniurets, sulphurets, etc.

Hot solutions of potash or soda have probably sometimes formed the first deep solutions, and deposited in the shallow, less compressed, colder sections, the first simple mineral supplies, which, gradually uniting by natural causes with their different favorite elements, formed the present more stable base mineral secondary compounds.

That one or another of the hot solutions obtained solvency is strongly substantiated by the fact that metamorphism has been always apparent when the minerals are found in such concentrated forms; whilst the invariable disintegration and decomposition of the alkaline rocks of the shallow sections of veins would mostly favor the acidified, highly heated, deep-water solvent, and precipitation by the released potash or soda from shallow sections, and subsequent secondary compositions peculiarly performed by slower natural causes.

Be it, however, as it may, it has been much owing to circumstances; and some of the minerals, such as the surface deposits of iron, manganese, lead, silver, gold, platinum, etc., with the alkaline earthy minerals, must have been formed in a more simple manner.

As, also, in districts that overlie volcanic calcinations of mineral oxides, that either remained as such, or compounded

with surface carbon, ocean chlorine, or organic elements; as the carbonates of copper, lead, etc., the chloride of silver, the carbonate, the phosphate and oxalate of iron, etc., etc., which all form at or near to the surface.

Remarkable illustrations of the first are seen in the dry, shallow sections of all copper veins, where water carries down carbonaceous organic matter, which decomposes and unites with the earlier formations of copper ores, in a comparatively short time. These carbonates are never seen below the permanent water-level, on first exposure, during the deeper excavations; but sometimes the copper will become thus partially carbonized even in a few weeks after, and stain the backs of the levels with their surpassingly gay colors of blue and green.

The second may be seen in the similar, more massive carbonates of lead, from the aqueous deposition, as well as those sublimations of oxide over actual volcanic heat, which have been changed to carbonates by subsequent evulsions or infiltrations of carbonic acid.

The third is that of the irregular deposits of chloride of silver, at and near the surface, which are found more or less in all uplifted silver regions, that had been previously covered by salt water; extensive modern instances of which have created such excitement at White Pine, at Hot Creek, and Reveille, in the State of Nevada. This whole region has been more or less elevated from the level of the ocean's bed to the present irregular contour of surface, and little doubt can be entertained that the more general solvent of the silver was boiling sulphuric acid, which collected and brought the sulphate of silver through the various fissures toward the surface, until it reached the presence of the oceanic solution of salt, and became precipitated to its present form of chloride, which, being further uplifted by the continued action of similar causes, increased results would follow until it became elevated to its present permanent position.

The fourth examples are the enormous masses of carbonate of iron that are worked from the layers found in the English coal measures; the numerous highly colored phosphates of iron, variously found at and near the surface, sometimes in the interior of fossils, and in fossiliferous ferro-manganic

sands; and the oxalate of iron, which has been formed in presence of, and during the decomposition of succulent plants.

THE FORMATION OF GOLD AT THE SURFACE, AND IN VEINS.

In the careful consideration of this subject, the following pertinent facts may be rendered subservient to our purpose, and must not be overlooked:

1. It has been often stated by reliable authorities that gold has *never been found entirely unalloyed with silver*, and that it is *very seldom* free from copper and iron.

2. In a gold-yielding country, the sulphuret of iron, from veins, invariably contains more or less gold; iron is also found as an alloy of gold, silver, etc., etc.

3. The sections of rock that contain gold-bearing quartz veins have been much tilted from their original positions.

4. All of the profitable gold fields and gold-quartz veins of the world form the borders of present or past oceans.

5. All of the rich gold-quartz veins are either in the Paleozoic, or very near thereto in the metamorphosed Azoic rocks.

6. All gold-producing regions have been invaded by extensive igneous uplifting action.

7. The veins conform more to those of "Segregation" than to "True Fissure," and consequently follow more or less closely the divisions of strata parallel with the mountain chain or line of general upheaval, and consequently they underlie the ancient ocean bed, in not very remote depth.

8. Those lodes which take a somewhat independent fracture, and occasionally traverse the divisions of the strata obliquely, are richer in gold than others that strictly conform therewith.

9. Much of the placer gold is *so differently characterized* that it could not have been all derived from quartz veins.

10. Platinum has never been found in defined quartz veins.

11. Alluvial oxide of tin is also distinctly different to the formations in veins.

12. These three metals are soluble in chlorine, and afterwards become insoluble to other natural solvents; the natural oxide of tin being also insoluble to even chlorine.

13. Iron, sulphide or oxide, prevails in all gold fields and veins.

Now, the only really practical solvents of gold are the hydrates of chlorine and fluorine; but, as the latter was not present in sufficient quantity, or having stronger affinity for silica and lime than for gold, it would have immediately associated with them; so that chlorine must, in some manner, have acted as its solvent.

Taking the gold deposits of the Americas, for example, we must suppose that the whole western coasts of the North, Central, and South Americas, were, at a not very remote period during their uprisal, sufficiently hot to cause the whole ocean border to *boil*, from the northern to southern extremes of the coast; whilst many regions of the land were sufficiently hot to free the chlorine from the salt that would have been deposited over the surface or in the fissures of the rock, which, being moistened by pure water from rains, would have fallen, and may have thus dissolved the gold, etc., etc.; or this chlorine solvent may have been sometimes formed by the action of naturally produced sulphuric acid on the chloride of sodium, in the presence of the oxide of manganese (as these three are generally present in such positions), and the formation may be then completed precisely as in Plattner's artificial process, for its solution and precipitation by sulphate of iron, which also has been invariably present in the gold fields, in considerable quantity.

This solvent of gold, if mixed with salt of oceans, which it must have been, would, when heated, dissolve silver, copper, and iron, which accounts for the *invariable alloy* of these metals, and provides for many other conditions. It was, however, much too soon for the deposition of such into veins, which, at this stage of refrigeration, could not have been formed, and applies to placer formations and pockets only.

At later periods, after the strata that adjoined the mountains had partially opened by contraction into fissures, the chloride of gold may have been supplied thereto, or distributed over the surface of the country, until precipitated in the veins or hollows at or near the surface, by potash, sulphate of iron, or the chlorine was released from the gold by mere volatilization, or even evaporation.

It is more probable that at a much later period, after the surface had become comparatively cold, and the fissures were better defined, the salt solution from the ocean penetrated the fissures to great depths, and that this chloride of sodium solution became intensely heated by the adjoining rock, under the extreme pressure thus created, and the water became partially chlorinated; or, as the heat approached nearer to the point of separation of its chlorine, that both quartz and gold, during long-continued action, dissolved, as it is well known that silver would more immediately be, from the rocks, and as the ocean waters also contained silver, this continued concentration would account for its invariable presence with gold. The manner of conveyance to the shallow portions of the vein would be as in the case of base metals, where it is probable that free gold was precipitated by potash, and that enclosed in sulphurets, by sulphate of of iron, etc., etc. So far as the free metals are concerned, however, the compound is so unstable that, with simple evaporation, a short time would suffice to free the chlorine therefrom.

The above theories will agree with the thirteen facts enumerated; but I am strongly disposed to favor that imperatively integral part which supposes that highly heated water slowly dissolves and hydrates silicic acid, which, if not the true solvent, at least holds and retains the metals in solution, until they arrive at, and are crystallized or precipitated in, the shallow sections of veins, in the peculiar ribbon or leaf-like manner, in the successive and extremely thin deposits that generally parallel and conform to the walls of mineral veins, as contraction causes them to recede from each other.

This peculiar lamellose structure of extensive veins, more particularly those denominated "True Fissure," have been, I think, produced by sudden intermittent jumps of the receding walls, during contraction; as it is impossible that such extremely slow average rate of travel should be mathematically regular; more particularly during earthquakes, which have applied their powers more or less strongly to all the districts of the world at certain times.

The expansions and contractions of summer and winter, that exert an influence to some few feet deep, may also have

caused this structure, as the surface rock, by abutting irregularly, forced the partially solidified siliceous waters up or down the vein, by varying the very thin spaces intervening the deeper walls of the vein, and compressed it during winter. In hard surface rock districts, this is not merely hypothetical, for, some ten years since, I had an opportunity of proving the old story to be true, "That the springs of water arose at the proper season of the year, whether rain fell or not," however ridiculous it may appear. In the reworking of an old Cornish mine, we had occasion to fix what is called a "fend-off" (a sort of "bell-crank") to the main pumping rod for changing the angle, in a shaft that was partially filled with water, up to within a few feet of the work, during an unusually dry autumn and early winter, when, although no rain had fallen, some time after the cold weather had set in, the water commenced to arise in this shaft and throughout the whole length of the mine, and gradually rose into a level that showed its progress in a very exact manner (as the level graded slightly from the horizontal, for better drainage); so that, as nothing had been thrown into this mine, and all the other surrounding mines were much deeper, this principle of *contracting surface* could alone account for the winter's flowing of the water. It appears, from very ancient fossils of those peculiar siliceous vegetable organisms called "Diatoms," that warm waters must have then held silica in a suitable solution for their growth; and the modern warm siliceous alkaline springs show another substantial fact: that where quartz is in solution, it does not precipitate until it becomes cold, and even then but very slowly. Thus, in the later and cold alkaline solution period, "Diatoms" ceased to grow, and the calcareous fossils of the "Desmids" prevailed.

These facts serve to still further substantiate the "Aqueous" theory for quartz formations, and show most palpably that the placer quartz and gold may be mostly of separate formation to that found in veins; and that, although some may have been broken off and washed from the outcrops of veins, the greater part—more particularly the large nuggets—were from pockets near the surface, that were disintegrated from the *then* higher ground by the force of water, etc.

Gold has continued to be formed, both at the surface and

in the veins, up to a very recent period, probably to the present hour; as often instanced in the placers by its being found deposited on wood in various stages of petrifaction, and sometimes in the crystallized "vughs" or cavities of quartz veins, and as recently embossed deposits on the perfectly well defined surfaces of the *previously completed* and *last formed* quartz crystals taken from the central portions of veins.

It will be necessary, in this connection, to caution the explorer and miner for these precious metals against the too often repeated statements put forward by authors, that the precious metals have not been found in Azoic rocks, as it may lead to serious errors, unless fully understood. It is true that they have not been found, no more than the base minerals, in the real *primitive bottom*, first fused rock, as it originally lies, and as described in Section 1, Chapter I; but, like those minerals, the precious metals have been found in whole systems of veins, that traversed some of the "Broken" and "Disjointed," metamorphosed, crystalline Azoic rocks described in Chapter II, Section 1, and Chapters III and IV, Section 2, where these adjoin the extensively metamorphosed Paleozoic secondary rocks that formed the ancient ocean beds and their more recent borders.

FORMATION OF PLATINUM, IRIDIUM, OSMIUM, PALLADIUM, RHODIUM, ETC.

Platinum, iridium, and palladium, are soluble in chlorine; but osmium and rhodium, when unalloyed, are at least very slowly soluble under ordinary conditions. These metals all carry strong family resemblance for infusibility, insolubility, malleability, hardness, texture, color, and manner of combination, and are generally found associated as alloys with platinum. Although oftentimes found in the placers with gold, it is not their invariable associate, as these metals, headed by platinum, take independent positions under the apparently imperative conditions of the presence of greenstone, eruptive rocks, or serpentine. It is also a remarkable fact that chromate of iron has been always found where these metals are most abundant, which must be because the same rock is a matrix for both, unless its presence is required in

some way, as the sulphuret of iron (originally sulphate) is for the precipitation of gold. These white metals (the associates of platinum) are of very high specific gravity, iridium being from 23 to 26—the *heaviest of all substances;* platinum being about 21.5. They form from two to five oxides, and from two to four chlorides. They are, moreover, so very infusible, that no natural fire can be made sufficiently hot to melt them; the artificially combined influence of the concentrated oxy-hydrogen blow-pipe flames being alone sufficient for this purpose; so that, remembering all these facts, and that they are the heaviest of all metals, I see no other way that they could have been brought to the surface of our globe, but in a similar manner (for the reasons previously stated) for the other metals; that is, as oxides. These oxides are notoriously unstable, and nothing would be required but short exposure for release and reduction to metallic states; which, I think, in this instance, was realized in the rock itself, which has been since disintegrated by water, etc., in sufficient quantities for the release and concentration of the small particles or nuggets of these metals that are invariably found near such eruptive rocks.

This opinion appears to be well substantiated from the facts that *these metals are not necessarily associated with quartz*, are *never found in quartz veins*, and are *always found in and around* these somewhat peculiar eruptive rocks.

If, however, chlorine has ever taken the part of a solvent, the more insoluble metals would have been rendered soluble by this fire oxidation, or by natural fusion with potash, and afterwards precipitated by the alkalies. These metals, being *naturally infusible*, and so much *heavier than the bed-rocks*, afford conclusive evidence that all the heavy metals must have been brought to the surface by some heated volatile associate, which, if not oxygen, may have been chlorine gas, so abundant before the colder formation of chloride of sodium.

This gas might have acted in an infinitely slow manner, on most minute particles or atoms, during the elevation of these metals to the surface, as their total quantities are extremely small.

CHAPTER VII.

THE PECULIAR CHARACTERISTICS OF "TRUE FISSURE VEINS," AND THEIR CONSTITUENT COMBINATIONS, POSITIONS, DIRECTIONS, AND DIPS—GENERAL COMPORTMENT WHEN TRAVERSING DIFFERENT STRATA, WHEN FORMING INTERSECTIONS AND JUNCTIONS WITH EACH OTHER, OR WITH CROSS-COURSES, DIKES, AND SLIDES—COUNTERACTIONS AND GENERAL INFLUENCES OF CROSS-COURSES, SLIDES, AND DIKES—SUMMARY OF THE EFFECTS PRODUCED BY THESE COLLECTIVE CAUSES.

"True fissure veins" are always found in metamorphosed (reheated spots of strata), chiefly in the "Azoic," less frequently in the "Paleozoic," and no good mine has been found in England above the "Triassic," or First Period of the "Mesozoic" or Third Time; but, in some other parts of the world, antimony, lead, iron, manganese, and mercury, in the Second and Third Periods of this "Mesozoic" Time, when sufficiently metamorphosed in veins, which are, however, not well defined True Fissures, but partake of modifications from extensive volcanic upheaval, and consequent sublimations.

1. "True fissure veins" are rarely found unaccompanied by others, and different systems or ages of their fractures can often be observed, as they have slidden at different times on each other.

2. They do not conform to the cleavage of the stratum, nor do they ever lie in the intervening division between two distinctly different strata.

3. They do not generally decrease, but rather increase their width and riches, at the greatest depths attained by man, although an apparently occasional individual instance occurs of the reverse.

4. Their encasing walls are remarkable for regular definition, smoothness, and unctuous or soap-like clay surfaces.

5. Their constituents of matrices and minerals are always found in laminations more or less conforming to general parallelism with the encasing walls; and, when short diagonal "splices" or "vughs" occur, they are also almost invariably on their edges.

6. The minerals are sometimes found in most distinct individual courses, the one beside the other, or in different parts of the quartz vein's width; at other times, speckled indiscriminately throughout, or in occasional stones of each; whilst, more frequently, they are so intimately mixed that they cannot be separated by hand.

7. Thus, the different metals are associated side by side with entirely different and numerous elements: the permanently insoluble oxide of tin beside the sulphurets of iron, copper, zinc, and sometimes lead; or arseniurets, oxides, carbonates, etc., of the one or the other, some in massive and others in crystalline forms; all of which, I presume, are derived from the original oxides, the oxide of tin alone retaining that insoluble form, whilst the others have passed, or are still passing, into other combinations.

POSITIONS, DIRECTIONS, DIPS, AND GENERAL COMPORTMENT WHEN TRAVERSING THROUGH DIFFERENT STRATA, EACH OTHER, OR CROSS-COURSES, DIKES, AND SLIDES.

8. "True fissure" veins take independent paths through all of the metamorphosed strata that lie within their course or dip. If, however, a stratum of rock overlies those that had been metamorphosed before, the vein *does not* pass out beyond the earlier heated spot, into that since deposited thereon.

9. They partake somewhat of parallelism, for each age of fracture, but take all bearings and dips at their different ages, as governed by the lines of contraction of the age.

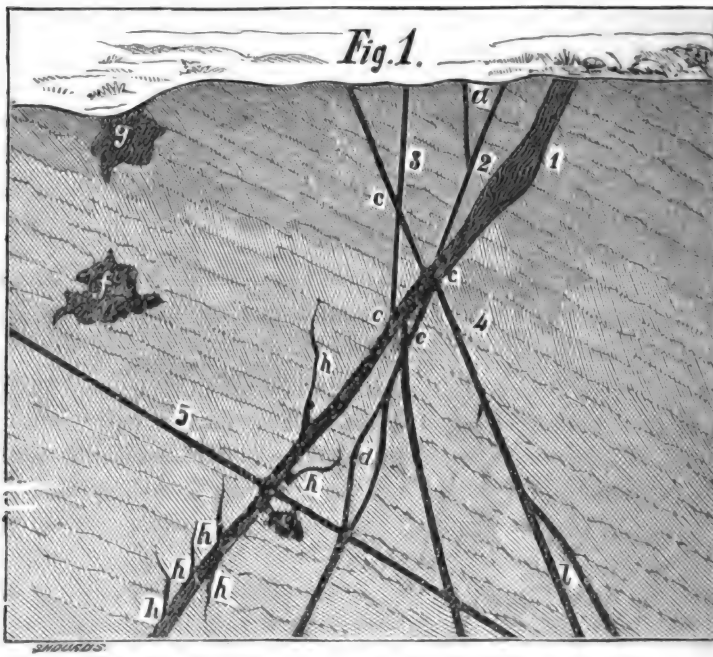
10. The veins of the *one parallel*, in the *same* complicated system, will all be richer in minerals of similar kinds, than those that run transversely thereto; not, I think, from any *difference* of *magnetic* influence caused by bearing, but from *age of fracture* alone, and consequently greater contraction for better solution and precipitation of the minerals.

11. The direction of veins seems to have been greatly

influenced by the adjoining ridges of the more primitive granitic rocks, and vary their degrees of bearing and dip accordingly, and the richer veins generally parallel such influential causes for conformity.

12. However near the systems of veins or districts may lie to each other, such influences will apply, as have been particularly well displayed in Cornwall, where, commencing at the St. Just District, near the Land's End of England, the north and south veins have been most productive for copper and tin; at Marazion, those bearing northwest and southeast have been most profitable; whilst, in the centre of the county (only about thirty miles inclusive), at Camborne, Red-

Fig. 1.



ruth, Gwennap, and St. Agnes Districts, those bearing east and west are alone mineralized. North and south bearing mountains prevail throughout the world, and they as often govern the direction of veins; but, when otherwise, profitable veins are found on the slopes and foot-hills of mountains at all angles.

13. "True fissure" veins seldom dip less than 45° from

the horizon, are frequently near to, and sometimes quite vertical; each vein takes independent direction and dip, often passing forward and downward through each other, at all angles within these limits; one may, for instance, dip northerly at 50°, whilst another overlying this may also dip northerly at 60°, and pass down through it; a third may still overlie and dip northerly at 85°, which also, after passing through both, may change its dip from north to south; a fourth dips south through all these at 70°, or any other degree; whilst a fifth may be a "slide," which may also occasionally shift or disorder the lode; the whole being also of somewhat different degrees of direction, and traversed by cross-courses that partake of similar, but transverse, differences of the angles of bearing and dip. On this figure, *a* shows a Y intersection; *b*, an inverted Y intersection; *c*, *c*, *c*, X intersections; *d*, a "horse" in the vein; *e*, a "carbona"; *f*, a "bonanza," or pocket; *g*, a surface deposit; *h*, *h*, *h*, "feeders."

14. Certain places of "true fissure" veins, almost invariably where the dip is more vertical, contain most mineral.

15. Certain directions, and corresponding parallelisms, of "true fissure" veins, contain more mineral, in all districts, than other directions of the same veins.

The two last are general rules, which must have been noticed by every thoughtful practical miner; and although the reasons have not been yet made apparent, some tangible cause must have created such invariably marked results. As it is very important that this should be fully understood by the miner, and more particularly by those entering new districts, I will endeavor, by the aid of two illustrations, to explain both the nature of, and reasons for, this occurrence.

First, let Figure 2 represent a vertical section of a fissure that had thus changed its dip from that of A to B; and again from C to that of D. A and C are the profitable portions of the vein, simply because B and D are *more contracted*, and *prevented an equally free passage of the mineral waters.* The arrows represent the *horizontal line of contraction*, that opened the rocks from *original contact* for the *after infiltration* of the matrices and minerals. Now, as the horizontal line marked by the arrows shows the *direction* of the separation

of the walls of the vein by contraction, so will the corresponding parallel lines at A and B, C and D, measure the *amount* of this contraction through *similar lines* in the vein; whereas, the width of the vein must be measured, in each case, at A and B, as well as at C and D, by *right-angled* lines,

Fig. 2.

to the *separate* and *different dips* of the vein at A and B, C and D.

If any man should fail to understand this argument, from the sketch, let him trace off, on transparent paper, the *singl* line that shows the left-hand wall of this vein, and move it in a vertical position with the bottom edge of paper resting on the table, in the line of contraction marked by the parallel arrows, a distance to the right that equals any one of the parallel measurements of travel marked A, B, C or D, and he will find (because these are all equal and parallel to each other) that this left-hand wall, when thus correctly moved, will correspond to the right-hand wall of the vein, which, of course, when first fractured, also corresponded. Or, let h trace this line with a needle's point on a piece of card paper,

and cut exactly through this line that thus marks the left-hand wall, with scissors, and he will have an exact representation of the country rock (or bed-rock) on both sides of the vein, which, of course, touched when cut as well as when fractured; so that, by holding the left wall in the left hand, and the right wall paper in the right hand, he may thoroughly satisfy himself in every way regarding these movements, and that, immediately motion is given from actual contact, a consequent difference of width ensues, and that no other direction for travel will produce similarly right-angled widths for the same parts of the vein.

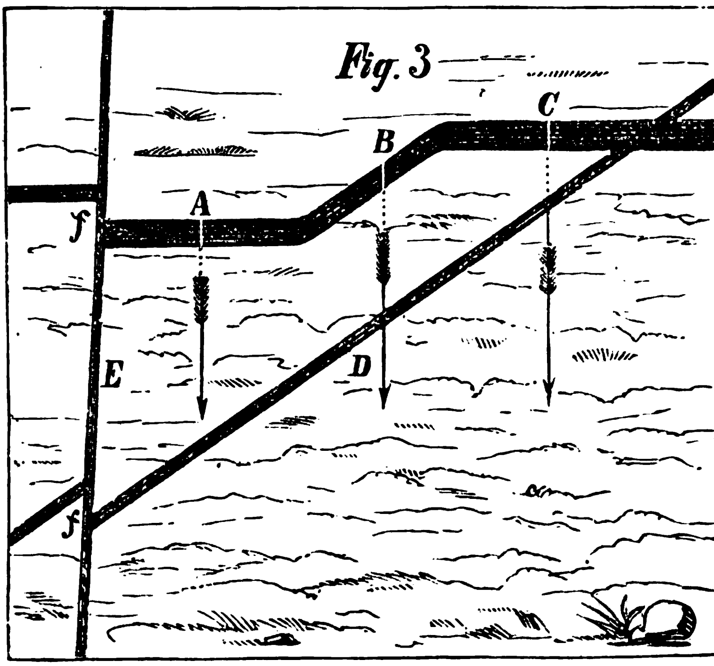
It therefore becomes apparent that where the dip was greater, the vein was also larger, and at E, where it is supposed to be horizontal, it is of no width whatever; and, consequently, more freedom for the conveyance of mineral waters, and subsequent infiltration of minerals, prevailed in such open sections than where the vein was more contracted.

So, again, referring to the portions of the veins that, having certain surface bearings, are richer here than there (and which sometimes may apply, for similar reasons, to "caunting" and "cross veins), it will be only necessary, instead of looking at the *vertical section's* line of contraction as *regards dip*, to take a "*bird's-eye*" view of the *surface* or *ground plan* of the veins, as shown by Figure 3, and, regardless of the last section, to ascertain the *bearing by magnetic needle* of the *line of contraction* that caused the withdrawal of the walls and opening of the fissures.

Let Figure 3 represent the ground plan of three veins, a regular vein, a caunter (or diagonal vein), and a cross-course; the bearing of the line of contraction, according to the previous argument would be at or about a right-angle from the average direction and the widest part or parts of the principal vein, as shown by the arrows.

It appears as plain on this plan as it did by the section, that this geometrical, or merely mechanical explanation, shows sufficient reasons for greater spaces at A and C than at B, and consequent room for deposition of minerals; and that no greater difference in the principle of action exists between the vertical and the horizontal than that the line of sectional contraction of Figure 1 is a constantly close approximate to

that of the Earth's surface, or a tangent to the Earth's radius, whilst that of the plan, Figure 3, is as variously changeable as the direction of the veins of each individual district throughout the world. I hold this to be a novel and tangible reason for this notorious rule for richer portions of veins, and believe that very often it may also be the reason why the flat



veins, "caunters," and "cross-courses" are less mineralized than those that lie more transversely to the lines of greater contraction.

Where an occasional exception occurs to this rule, the subsequent decompositions have, for similar reasons, again dispersed the minerals.

16. Free passage and plenitude of water are regarded as essential to extensive deposits of the minerals; which also favor these reasons, and that such portions were, and are being, mineralized by infiltration.

17. Lodes often vary in size for other reasons than those of direction and dip; and the larger places are generally

much richer (for the reason of such free passage of water) than their more compact sections.

These frequent expansions or "wallows" of lodes, between irregular walls that must have been first parallel, may have been produced by highly heated water (as described in Chapters II and VI), which would dissolve or hydrate silicic acid (quartz), and the silicates of potash and alumina from the adjoining rocks, and thus add to the general solution more of the solvent or matrix, silicic acid, with the alumina or clay for the joints and walls; whilst the precipitant of potash would also be similarly watered and released from its affinity by this high degree of heat, and provide an assistant in the precipitation of minerals at shallower sections of the vein, after the pressure and temperature had become suitable for this change of action.

18. Lodes (having also the other necessary conditions) which vary in direction, dip, size, etc., are more plentifully supplied with minerals than those of perfect regularity.

19. When mineralized lodes are intersected or crossed in length or depth by "caunters," "cross-courses," "slides," or "dikes," they are generally improved at and near their junction; although sometimes the reverse is the case.

20. A lode is often mineralized on the *one* side of all such intersections, and not mineralized on the *other* side.

21. A lode is often larger on one side of a cross-course than it is on the other side.

22. A lode is often shifted downwards in the manner and direction as illustrated by Figure 1, at *c*, *c*, and *c;* and sometimes horizontally, as shown by Figure 3, at *f* and *f;* but it is more frequently found on the obtuse-angled side, and when not thus situated, if the stratum were transparent, it would be seen that a very small intervening block of country had been shifted to accommodate the more regular motions of the much more extensive controlling sections.

23. The *length of any one* lode is *generally*, and the *total length of all the lodes* of a system of veins that have been thus shifted, is *invariably*, *less* than the present length of the ground in which they now lie; because (as generally supposed) the strata have slidden, or contracted and shortened, more in the one direction than in the other.

24. Other guides to the positions of slidden lodes are the comparative percolations and mineralization (ascertained practically by taste or analysis) of the waters from both ways, and a slight turning of the vein towards its disjuncted part.

25. True fissure veins seldom crop out boldly above the surface of the ground. This is a general rule in Cornwall.

26. Rich lodes have their completely barren spots, and the poorest lodes have occasional stones of rich ores, which should not infatuate and deceive.

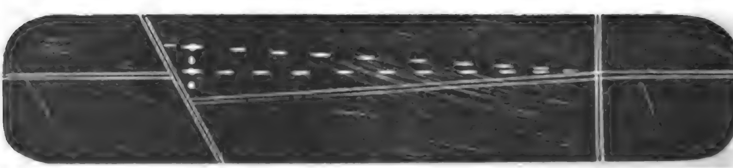
27. Lodes of regular yield are the desideratum of the miner. They are easily worked, and are more reliable.*

THE EFFECTS THAT ARE PRODUCED BY THESE COLLECTIVE CAUSES

Should be carefully and continually observed, as they will serve to guide you, to an eminent degree, in the development of the mine. Passing by the minor facts, the subjects of intersections as governed by bearings and dips, disjunctures and heaves, cannot be too well studied, for the correct positions of shafts, levels, etc., as well as for machinery; seeing how many really good mines have been, and are now being, poverty-struck by such ill-considered practices.

It will suffice to more particularly caution the miner against this one great and general mistake, by the following three-fold illustration and example, which will apply also to deposits of ore that almost invariably dip more or less, the one or the other way.

* I am of the opinion that although the various strata of coals and bed-rock have actually changed their places, in a *vertical* manner since deposition, the fissure veins have not been *horizontally* moved to anything like the extent accredited, but were thus *formed by fracture*, as explained by the accompanying figure.



The cross-courses were first fractured; then the regular veins, which would naturally sway the line of fracture toward the obtuse angle, because the *lesser* distance would give *less resistance*. This is frequently illustrated on the plastered ceilings of rooms. The first cracks run in a regular uninterrupted manner, and the second but intervene between the others, as illustrated.

FIG. 4.

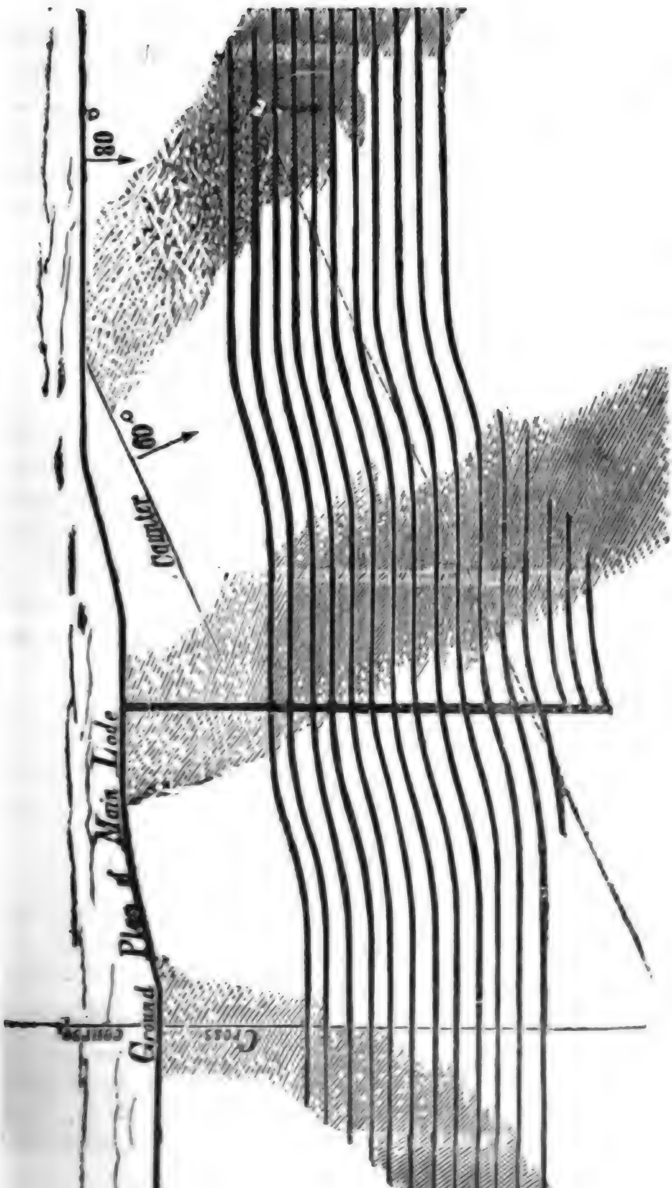
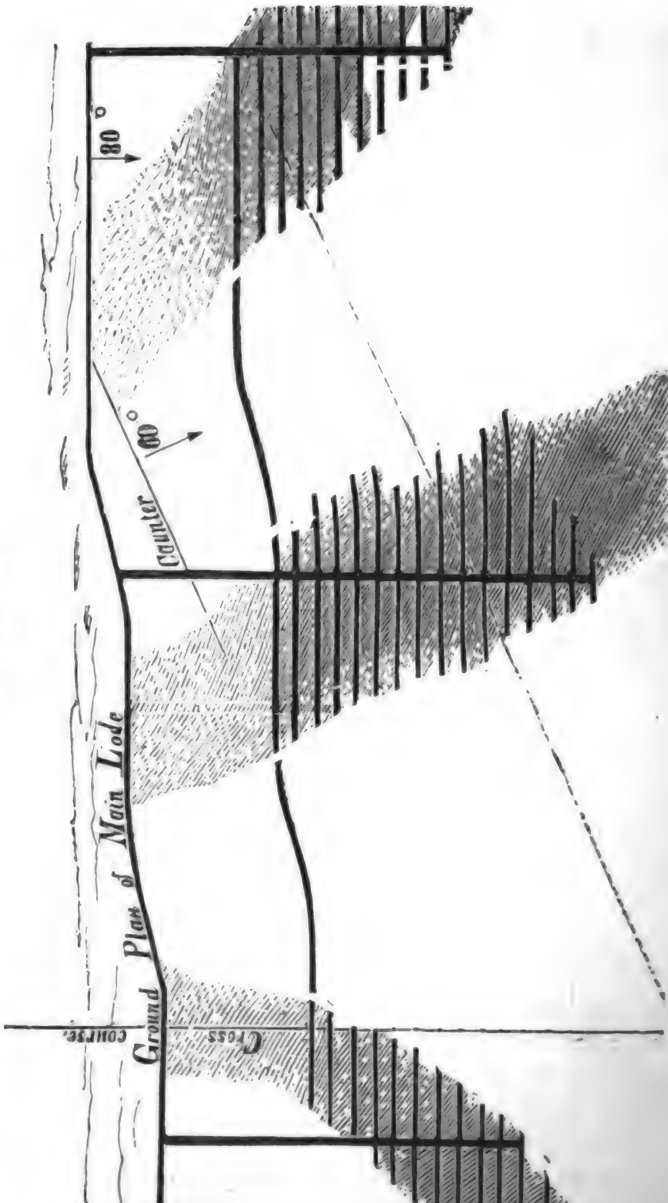


FIG. 5.



Cut 4 represents a bird's-eye view or plan of a piece of hard and expensive ground, that is 2,000 feet long, in which there is a regular east and west lode, that dips south at 80°; this vein is intersected by an oblique-angled mineralizing "caunter" vein, at the one end, that also dips southerly at 60°; in the middle of the ground, a deposit of mineral is shown, on the east and west lode, that dips east at about 70°; and, at the west end, a mineralizing cross-course dips west at 60°. Thus lie three valuable deposits of mineral; the one in the middle, and the others at each end, following the influences of the "caunter" and "cross-course, and each deposit is about say two hundred feet in length, as shown by the darkened central portion, and those that adjoin the intersections.

Now, it may be very easily perceived that this mine would have been unprofitable if worked as there described and shown by the positions of the one shaft and several very long levels. For the shaft is too far west for even the central bunch, which is continually worse at deeper levels; it is too far off from the fast departing mineral that adjoins the under side of the cross-course, and still worse placed for the eastern intersection of the caunter, which, from being so oblique and dipping so much less than the main lode, carries the mineral that is deposited under the intersection rapidly eastward, entirely out of reach of this one shaft, if not into your neighbor's ground.

If such deposits are worthy of being worked, they are worthy of being wrought properly, and therefore shafts should be sunk on each, with separate mechanisms, where shown by Cut 5, to command each deposit, at about midway between the depth where it first commenced to be profitable and the deepest profitable depth of the district; so that as little length of levels as possible would have to be driven through unmineralized lode.

Or *two* or *three distant*, exploring, ventilation and drainage levels could have been driven from the central pumping power, if deemed more advisable, at distant levels, as shown by Cut 6.

This will very often apply to one "shoot" or dip of deposit, and seldom in the manner illustrated, when it will be more

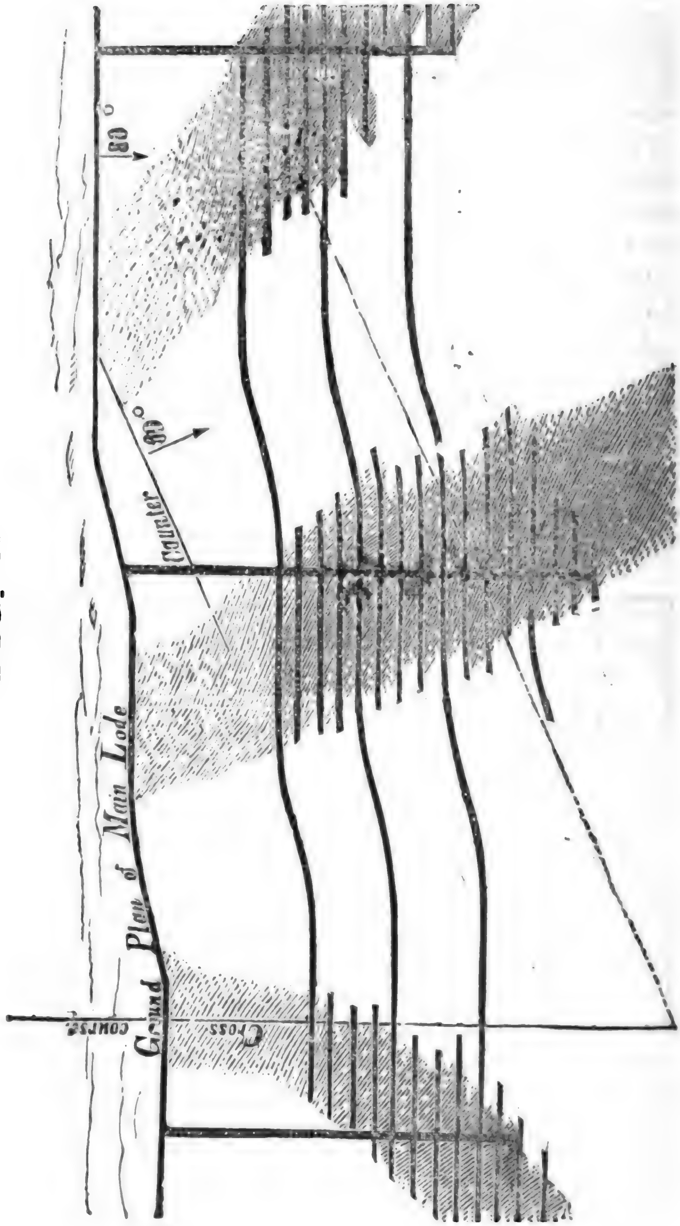


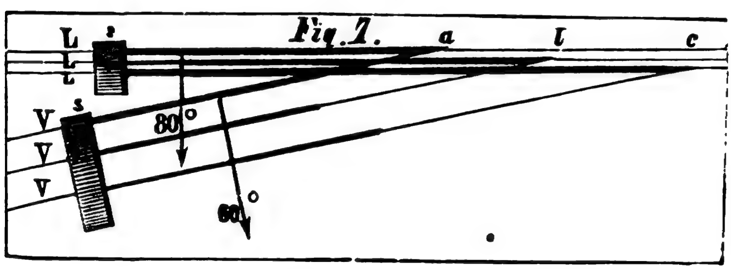
FIG. 6.

advisable to have two shafts for one deposit—the one for hoisting, the other for pumping—situated from two hundred to four hundred feet asunder, embracing a similar section of the run of ore ground, and affording much better ventilation.

The engine-shaft will be more independently effective for pumping of water; whilst each will aid the other in hoisting, ventilation, and traffic, thus aided by double position, so that the mine will be more expeditiously developed in many ways, but particularly by having four or six sets of levels instead of two only, continually opening ore ground.

As it is most important that the rates of advance of such intersections should be, for many reasons, well understood, the following will show an easy method of finding it by construction:

Thus, in Cut 7, where the first levels from the shafts are communicated, let L, L, and L, be the regular lode, and V, V, and V, the intersecting vein at three different levels,



canting at the angle shown; S is an engine-shaft on L, and S is a shaft on V. The distances between L and L and L are each such as this main lode would gain south in say one hundred feet deep; now, by marking off the corresponding distances that V, V, V, would gain southerly at similar depths—say in this case about thrice as much—and drawing the lines according to the bearing of each vein, we thus arrive at the different points of intersection, *a*, *b*, and *c*, and perceive that its dip is traversing eastwardly dangerously fast from us.

Another good and practical model may be made at a suitable scale of the veins of a mine, as they lie *in situ*, by making an open top box of the size and shape of your sur-

face ground or grant, and as deep as man ever works; in which wires may be passed through the ends and sides, so as to exactly agree with the different lodes' relative positions, bearings and dips, so that their intersections may be seen at a glance, at the different intended levels of the future.

The best, most accurate, and reliable, for *past* workings, are, however, good plans and sections, which should be always kept closely posted, in all respects, and hung on the walls of the office, that all concerned may see them as often as desirable.

The value of the lode at each fathom driven or sunk through should be invariably recorded on such sections, for future reference, when setting tribute "pitches" or contracts. A duplicate section may be used for this most important purpose.

CHAPTER VIII.

THE MORE GENERALLY RECOGNIZED PREMONITORY INDICATIONS, IN THE SHALLOW PORTIONS OF VEINS, FOR PROBABLE INCREASE OF MINERAL AT DEEPER SECTIONS.

The most prevalent and congenial matrices of the veins are quartz, fluor spar, and calc spar; which control, to a certain extent, the quantities and kinds of the minerals.

1. Quartz (silicic acid) is an universal matrix for all.

2. Fluor spar (fluate of lime) is generally favorable for lead and copper.

3. Calc spar (pure, crystallized carbonate of lime) is often favorable for shallow depositions of silver, and sometimes lead, in certain magnesian limestone districts.

Heavy spar (sulphate of baryta) is also found associated with quartz, fluor spar, and calc spar, in moderate quantities; it appears to take its position, however, more as a chance mineral than significant matrix.

Gypsum (sulphate of lime) also occupies an occasional place in veins and pockets with the leading matrices, that carry the minerals of silver and lead; but appears to have exerted little influence in their mineralization. Dikes of gypsum, which are notoriously deficient of mineral, are more frequent.

4. These matrices being present in a vein, some other indications may be named, amongst which a properly defined vein lies most important; for really valuable deposits must be extensively maintained throughout, as well as contained therein.

A well defined vein conforms to the descriptions given of such in the first part of Chapter VII, which need not be repeated here.

5. It should not be too small to contain a sufficiency of the

particular mineral or metal sought; nor so large as to unduly scatter the mineral throughout the matrices of the vein; the most approved width is about four feet, and when this is much exceeded (for the above reason and the extra expense of securing the ground), the practical value is seldom enhanced.

6. The matrix, whether quartz, fluor or calc spars, single or mixed, should expose that *peculiarly congenial appearance* so familiar to the miner's eye, yet difficult to be described, which should, however, be closely studied by the novice, in the well known rich lodes, as well as in districts equally notorious for their poverty; that he may also recognize the *uncongenial, non-bearing* spars. The best characteristics for prosperity are the following: They should not be too compact, but somewhat friable, "rotten ripe," or "sugar like"; although giving occasional signs of crystallization, they must not be too much crystallized; the quartz should not have a gem-like transparency, but be, in its pure state, white, or stained, by the oxide of iron or manganese, to cream, rust, or rose colors; it should expose, on fracture, a *moist, full and generous appearance*, rather than "dry and hungry"; a repletion of congenial quality, not depletion.

7. It should be of the specific gravity of 2.8, and not of 2.3.

8. The oxide of aluminum (alumina, fluccan, or clay) is invariably present in abundantly mineralized veins, forming the much to be desired clay-plastered walls, as well as permeating throughout the mineralized portions of the vein. This is, of course, an oxidized metal, and as much a mineral as any other; but it appears to have been deposited without the quartz, and not within, as was the case with the other minerals, and was therefore a subsequent formation, thus far favoring the theory fully described in Chapter VI, where potassa was supposed to have precipitated the minerals from their acid solutions. The alumina (fluccan or clay), *being present in abundance*, is therefore a good indication, because it must have been *derived* from the *adjoining feldspar* during the decomposition of this double *silicate of potassa and alumina;* which must also *have released* its more soluble, constitutional *potash* as a *general precipitant*, whilst the alumina followed

more slowly in mechanical suspension, to fill the after spaces.

9. Chlorite, a mineral that varies in color from olive to bright green, and talc, which is from green to gray—both partaking of the same unctuous feeling as clay—are also looked on with similar approval as indications.

10. The oxide of iron appears to have its point as an indicator, as in the "gossan" of Cornwall, which is believed to be an infallible mark on the *back of a lode* for copper and lead at deeper levels.

11. Sulphuret of iron, too, when in considerable quantity, has a similar, but *deeper* intimation, that copper will be found still deeper. As a rule, the oxide is mixed with an extensively disintegrated quartz, which was the result of the decomposition of the sulphurets, that preceded the oxide, and thus released the quartz into friable condition, to a depth of from a few feet to that of, in rare cases, some two hundred feet. The sulphuret next follows underneath in like manner until a change appears, and copper sulphuret is attained.

The reason that *iron is such a general indicator* in mineral veins is, I think, more owing to its *prevalence in the adjoining bed-rocks*, than to any chemical effect; and like alumina, chlorite, and talc, it shows by its presence that sufficient actions had been at work for solvency, and that *ample space* had existed for free traverse of *iron*, and therefore the *other mineral solutions*. It, in other words, evidences continuous water channels in the vein, and by its presence all the other accompanying minerals that chance to be around.

12. Good indications for increase of copper and lead in depth are to see an occasional speck or stone of either, or the colors of the blue and green carbonate of the former, or the yellow or brown carbonate of the latter, above the water-line. So, also, for all the minerals, the other conditions being present, as to the proper definition of the vein, etc., their various ores being found in small quantities in the shallow portions, favor an increase in depth. Tin lodes require the presence of oxide of iron, and a blue stone called "capel," which is composed of quartz, schorl, and hornblende.

In extensively igneous elevations of country, this rule seldom applies, because the minerals are formed by different

means, and therefore generally expose the equally good parts of vein or deposit, at or near to the surface; so that, although the *spirit of speculation* for such similar increase *may be admired*, the *practice* must *be deprecated.*

13. Variations in the size and component qualities of veins are favorable to their mineral yields, whether the change is caused by difference of direction in length or depth, or from decomposition and disintegration of the encasing walls, for reasons previously explained. An occasional "horse" in the vein is also more favorable than otherwise. In other words, very straight and regular veins seldom realize profitable returns.

14. Mineral water indicates proximity to its source, and consequent approach to large deposits of minerals, both when they are in actual course of deposition from such solutions as when they are being decomposed into after solutions. Large deposits of mineral, however, have been frequently found intervening the stages of formation and decomposition that afforded no such evidence.

15. Hot water is often the precursor of mineral deposits, which, by percolating through their sulphurets, warm the water to a higher degree than would otherwise result at similar depth.

16. In ordinary acceptance, embossed or "boldly cropping" veins are favored, because they expose evidence of continuation, rather than plenitude of mineral.

17. In "true fissure" veins, it is a most unusual thing to find much outcrop; and, when present, it is not a good sign for mineral wealth.

The vein should be so friable as to give way to, rather than resist, the effects produced by washing, freezing, and consequent disintegrations from water, which, aided by chemical decomposition, should produce "gossan."

It must not, however, be forgotten that each district has, to a certain extent, peculiar indications, beyond those already named, and that some of these are occasionally of no very material value.

SECTION II.

EXPLORATION.

CHAPTER I.

PROSPECTION.

From time immemorial, it has been the first duty of the miner to explore or prospect the surface of a country for minerals and metals, and for many ages this source must have yielded a sufficient supply for the limited demands of the ancients; but, after some thousands of years had passed away, man discovered, not only more metals, but infinitely varied uses to which they could be applied and rendered eminently subservient to his purposes, the most wonderful of which are the printing press and daguerreotype; the power loom, the steam engine, and the electric telegraph; magnetism, galvanism, and chemistry. It is, however, during the last century that its developments and consequent powers have far surpassed all previous ages; for the steam engine has modified the maxim that "heavy bodies are slow to be moved," and the electric wire has more than realized the poetically wild expression of Shakspeare, by "putting a girdle round the Earth in forty seconds."

The metals are not only a necessity for, but an actual measure of civilization; for it cannot be denied that the country which possesses the greatest weight of manufactured metal per man has attained a corresponding degree of civilization and influence in the world, which cannot be perpetuated without an inexhaustible supply; it is, therefore, imperatively necessary that we should economise by every available

systematic means, and render these ruling commodities cheaper than they can be supplied from elsewhere.

Remove the metals from the world, knowledge and power will sink into oblivion, the glorious light of civilization wane, and man would merge into the hopeless gloom of dark-ensuing ages. In modern mining, the business of exploration becomes again the most important of all the phases of the miner's practice, for preliminary judgment governs the after success or misfortunes by the wise or unwise selections of mineral veins. To be a good prospector is, in itself, a business that requires many qualifications, as well as much study and practice. Constitutionally robust and enduring, he must be as wary as the Indians, and accustomed to their ways; be a good shot, cool as a statue in a fight, and brave as a lion; he should be a good rider, and familiar with the management of horses, under many, ever-varying circumstances, anticipated at daylight for realization at night, for water, feed, safety, etc., for the animal and himself; and, lastly, but certainly not the least, a very good plain cook, and frugal eater. If not in possession of such qualifications, he had better stay within the more tranquil and congenial pale of civilization.

CHAPTER II.

HOW TO EXPLORE.

To obtain a suitable outfit is the first duty of the prospector, and the following list of articles and suggestions may be of some value to the uninitiated:

He should have two pairs of thick blankets, a buffalo-skin, or, if possible, the more luxurious comfort afforded by a pneumatic rubber mattress and pillow, which are very light, pack closely (after the exhalation of air), and, by protecting the body from the emanations that arise out of the damp ground, prevent disease by increased accommodation. Two strongly buckled leather straps, for securing blankets, mattresses, etc., when packed for traveling. A suit of strong gray clothes, a change of flannel underclothing, a slouch cap, and a strong pair of boots. A Henry's or Spencer's breech-loading rifle; a full-sized Tranter's, Smith & Wesson's, or Colt's six-shooter; a leather holster, with waist-belt, and a good hunter's knife. A mule, or a mustang horse, accustomed to mountain life; a bridle, having a short whip attached; a horned saddle, fitted with rings for securing blankets, saddle-bags, water-canteen, etc.; one of the stirrups (I prefer the left) should be fitted with a tube for receiving and supporting the muzzle of the rifle, the upper end being suspended by a leather yoke, so riveted at its middle that one loop can be tightened on the taper rifle-stock, and the other passed loosely over the saddle-horn, that it may be freed for immediate use when necessary. This same yoke can be used for "hobbling" the animal at nights, by punching two holes at a suitable distance from the ends, to allow sufficient freedom to the legs, securely tying with buckstrings, passed through these holes, and stop-knotted, so that

the animal shall not stray too far away, when the scattered pasturage prohibits the use of a picket-rope. A small "poll" pick, and a light and solid wrought-iron baking-dish, of the shape of the prospector's pan; to be used, as required, for either purpose. An eight-inch wrought-iron frying-pan, a coffee-pot, tin-cup, fork and spoon; a good supply of matches, some soap, a towel, etc.

These, with a pocket-compass and spy-glass, constitute a first-class prospector's outfit, and with such (excepting only the buffalo-robe, mattress, and pillow), the writer has made a lone journey of eight hundred miles, over fourteen ranges of mountains, in thirty days, cooking bread and victuals, *en route*, from the following provisions: Flour, fourteen pounds; bacon, eleven pounds; tea, one-half pound; a box of yeast-powder, with pepper and salt. These, varied and assisted by two jack-rabbits shot on the way, desserted with good appetite, were more relished than better food would have been under less active and invigorating circumstances.

It would be folly to attempt a minute description of the general subtleties of sage-bush cookery, as most men will succeed therein as well as I did, and will be enabled to get on sufficiently well to prevent starvation (if not to realize the value of tasting grief, that they may learn to live more contentedly afterwards); and necessity will dictate many varying dishes, by roasting, frying, and stewing.

There is, however, one suggestion that may enhance comfort, when passing through an unusually dangerous Indian country, when fires must be avoided at or near your camping-ground, and cold collations become a consequent necessity. In such circumstances, I boiled, when in security, one-fourth of a pound of tea in a quart of water, for ten minutes, and after removing the leaves, continued the boiling of this strong tea-water until it evaporated to about a pint, which I carried forward for use when required; it will be found that one spoonful of this, when added to a cup of water, makes a much more palatable and refreshing beverage for washing down your frugal meal than water, and it will prevent the headache that will otherwise result.

This, being under peculiar circumstances, was worse fare than such men generally enjoy; for, as I was alone, and trav-

eling over strange ground, my poor, unfortunate animal, even thus freighted, with self, supplies, etc., had to pack two hundred and fifty pounds thirty miles per day, under a scorching sun, over mountains and alkaline flats, partaking of her scanty fare of chance bunch grass, during the night, most miserably restricted by hobbles. Mules have been much extolled for this work, and they may be better on the hard mountain; but, for the general purposes of exploration, the good, hardy, enduring mustang, if free from vice, is not only faster, but much easier for the rider, and on soft ground travels freely, where the mule, by sinking deeper from insufficient area of feet, is retarded at every step; moreover, the mule's back is so ridiculously too straight for the requisite stability of the saddle when traveling over undulating country, that this alone would favor the use of the horse. As to their comparative measures of amiability, neither can claim much superiority, for the old saying of "Stubborn as a mule" may be equaled by a new one, "Wicked as a mustang."

These desirable equipments are too often curtailed by deficiency of cash, and those that are imperatively required are selected at discretion; but, in no instance (unless he is prospecting for a lunatic asylum), should he expunge more from the list than the horse or mule, with their appendages; the buffalo-hide, rubber mattress, pillow, one blanket, and the rifle; and then he should, if possible, obtain the substitute of a faithful donkey, to pack his baggage and share his solitude.

Before moving yourselves away from water and grass, it will be necessary to resort to your most superior judgments for the whereabouts of the next suitable camping-ground, which I have seldom failed to anticipate, from the following indications:

In viewing a distant mountain, take particular care to measure with the eye the extent of mountain-slope that is drained by any particular cañon; for, the greater the expanse of such surface of drainage, the more likely are you to find water. Granite, by absorbing less, yields more surface water than clay slate, and clay slate more than limestone. Snow-capped mountains are more to be relied on, in such positions, than those that are uncovered. Patches of willows, cotton-wood, wild oats, rye, and other greens, indicate, by their

extended growth beyond the mouths of cañons, the presence of water, which may be often seen at great distances.

Water frequently runs, during the night and early morn, much further down the flats than after the sun's meridian heat has evaporated a portion of the running stream and its upper tributaries; so that, in apparently dry rivulet bottoms, moisture may be found, if not water, a few inches under the surface, showing that it has recently run thus far, and the probability that it still runs a little higher or nearer to the mountain gorge.

Where water runs, grass will also be almost invariably present, in sufficient quantities for transient feed. If darkness should overtake you, before reaching such a cañon, your animal will find water, by superior instinctive faculties, if unrestricted by reins, much sooner than you can.

It may be occasionally necessary to ascend a mountain that is deeply covered in snow, to examine some prominent out-crop; and if you have not the regular ten feet long by four inches wide snow-clog, you can readily make a substitute, by interlacing a few willows to form a support of two feet long by one foot wide, with holes in suitable midway position for securing them under the feet or boots. These will bear you up in very soft snow, and are much more easily made, carried and used than the others, which require considerable practice, for much advantage.

In cold weather traveling, it will be also very necessary to resort to extra artificial means for keeping the hands and feet warm, and a pair of kid or buckskin gloves or mittens, lined or covered with flannel, will be ample for the hands; whilst a barley-sack, cut into rectangular halves, wrapped and tied around the boots, will be superlatively effective in preventing the feet from becoming cold or frost-bitten. If you have no cord for securing the half-sack, you may first cut the sewing of the barley-sack, and then, after cutting it straight through its longest diameter to form two triangles, they may be bound around the boots, and secured under the hollow of the sole, and over the instep, by knotting the acute ends of the canvas.

Being thus prepared, the important questions arise: Where to prospect? Which formations should be sought? And what should be avoided?

CHAPTER III.

WHERE TO EXPLORE.

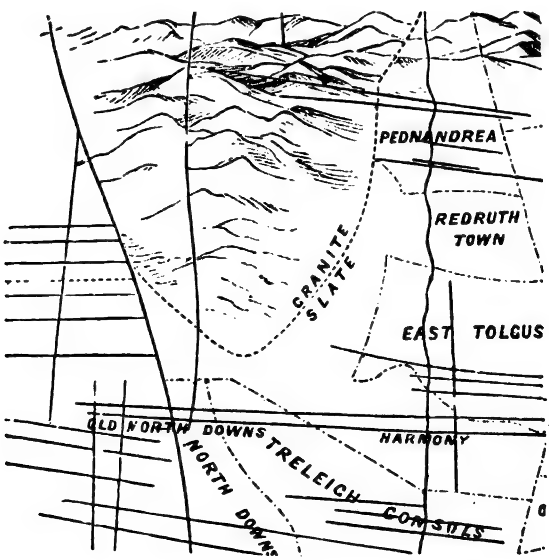
There are but very few general rules in mineral formations, and in some instances what was once conformable to rule has become so modified and disguised, by extensive volcanic action, that its original features cannot be recognized, but must be valued for as much as they are worth, under such uncertain circumstances; which have generally produced limited, irregular, undefined and scattered pockets of the base minerals, and when combined with certain circumstances, at more remote distances from volcanic heat, in the interior of primitive and secondary formations, the precious metals.

The history of the world's mining has, however, most clearly demonstrated this very important fact: that all of the great systems of true fissure veins, of the extensively profitable mining districts, have been discovered and wrought in close proximity to, or within a few miles of, the junction of the primitive with the secondary formations: sometimes in the former; at other places in the latter, and frequently in the both strata, at the same time and place.

This principle applies more palpably to the older, less disturbed, and more regular formations, and to the reactions that have been produced in the true fissure veins of Nature's laboratory, and to gold, silver, copper, and tin deposits.

Gold and silver, although strictly conforming to this position, appear to require the additional assistance of a partial disturbance by somewhat remote or subterraneous volcanic heat, to collect and concentrate their atoms, by some means (little understood); whilst the same power appears to lessen the previous deposits of the volatile base minerals by dispersion.

In this connection, regarding lead, antimony, zinc, mercury, and the other very fusible and volatile minerals, I have seldom seen a profitable mine, for either, within the distance of two miles from any primitive range, and then only in transverse veins to that formation, and the other veins of the district; but, with very few exceptions, they are found ranging from this distance to some few miles away. It should be remembered that very small patches of primitive rock, accompanied by the appropriate surrounding conditions, have produced some of the most extensive ramifications of rich veins in the world; so that very large primitive mountains need not to be always present, nor comparative mole-hills be despised; for where such arise in the congenial clay slates, or in metalliferous carbonates of lime and magnesia, there you should most delight to sojourn; for such hills, in Cornwall and elsewhere, produced in their immediate localities, near their junction with the clay slate, in both these rocks, enormously rich and lasting mines. (See page 63, and this cut.)



In the United States of America, there are four very extensive and interesting mining fields, west of the Mississippi Valley: the first of which commences at, and continues

from, the Guadalupe and Sierra Madre of Mexico, and passes, in a northwesterly course, through the Territory of Arizona, by several somewhat broken, parallel, primitive mountain chains, the principals being the Chiricahui, Santa Catarina, Mogollon, and Pinaleno ranges of mountains, all of which are known to be surrounded by the various slates and other metalliferous secondary rocks.

Ancient records, miners' relics, and excavations, have been discovered all over the interior: notwithstanding these demonstrations of past value, this country has been thus far but partially explored by modern miners, because of the persistent determination of the Indians to prevent the further encroachments of the civilized peoples on their country and hunting grounds.

The second commences north of the Colorado River, where the Sierra Nevada rises, and continues this northwesterly course, uplifting on its western slope, for hundreds of miles in length, the talcose clay slates of California; and, on its eastern side, numerous patches of clay slate and lime. This western slope of the Sierra Nevada is so well situated, for climate and proximity to the ocean, and so amply supplied with wood and general provisions, that it will undoubtedly become the most profitable, as it now is the most interesting and extensive, mining field in the world. For the reasons of being generally covered with soil or alluvial debris; the anxiety of prospectors to penetrate the unexamined interior; high rates of wages; partiality of capitalists for real estate; high interest to be obtained for money; and being further damaged by reckless market mining, as well as by the more *ruinous practice of erecting the various reduction works* before the *mines were proved* by shafts and tunnels; with many other general extravagances from unsystematic mining; the mineral resources of the country have not been exposed; but the day is not far distant when, after many local notions are forgotten, and mining shall become the precursor of milling, that the quartz veins of this State will be worked as economically as those of Brazil, Australia, and New Zealand; and hundreds of ledges will then be reduced at a profit that are now unvalued and idle, which will lead to the discovery of thousands more.

This range, after its departure from California, bends to the north northeast, and continues, by way of Shasta Peak, Mounts Jefferson, Pitt, Hood, Rainier, Adams, St. Helen's, and Baker, through the State of Oregon and Washington Territory, where similar analogy predicts mining success in the future. It then bends to the north northwest, and, after passing through British Columbia, enters perpetual snow; thus forming an almost entire line from Mexico, at about two hundred miles distant from, and parallel with, the coast.

When these northern countries of Oregon, Washington Territory, and British Columbia, become more thickly populated, the dense forests will be cleared, and the country rocks more closely examined, in the rolling foot-hills and gulches that are now inaccessible.

The third field, the Wahsatch Mountains, commences a little north of the Colorado River, some hundreds of miles east from and abreast of the second field, and runs north to confluence with the Rocky Mountains; forming the eastern primitive rock-rim of the immense volcanic basin of Nevada—passing between it and Utah—the western flanks being, however, chiefly in Nevada.

From the Sierra Nevada's slope to this primitive's elevation of the secondaries, the country is, with very few exceptions, a vast belt of volcanic clinkers, in which extensive mining districts cannot exist.

The mines that have been discovered east from the Comstock (which is on the Sierra Nevada) have been in connection with the few granitic islands that withstood this volcanic fusion, as the Austin Mountain, Battle Mountain, Trinity Mountain, and the mines at Unionville, which are within a mile or two of, and were uplifted by, the primitives of Rocky Cañon.

The Wahsatch Mountains, having all the advantages of the various granitic and the older secondary formations, that adjoin its both slopes, as well as its numerous spurs, being of favorable acclivity, and of varying distances from this monstrous volcanic cauldron; some parts will be favorable for base minerals, whilst other places will have the more suitably remote advantage for the production of the precious minerals and metals.

It is also probable that, as eastward distance is attained, moderately thick deposits of coals and iron will be discovered, in the more central basins lying between these and the Rocky Mountains.

The fourth field is that formed by the Rocky Mountains (which divide the water-courses of the Atlantic and Pacific rivers), as they trend northerly from the southern portions of New Mexico, through the Territories of Colorado and Wyoming; thence northwesterly, through Montana on the east and Idaho on its west, into British Columbia, where this mighty range closely approaches and parallels that of the Sierra Nevada, both bearing with the coast about north, northwest. In this enormous distance, the eastern slope will present constant variations, facing, as it does, such a vast plain, formed by the alluvials of all ages; under such circumstances, it is probable that the metallic minerals will be found in far distant sections, along its serrated slopes, as suitable local strata may encourage their presence; and that heavy and frequent beds of coals will be found, transversely approaching in the alluvial sloughs, at varying eastwardly distances, when remote from metamorphic action.

These are the genuine fields for such enterprising men, and where their indomitable perseverance will be more frequently rewarded by success.

After the discovery of the rich Comstock ledge, on the eastern verge of the Sierra Nevada, it was not strange that bold prospectors, favored by a magnificent climate, should have been infatuated, and enticed forward into the far interior, for the prospection of the unexplored land, that loomed, with all its distant, enchanting grandeur, and rosy beauty, before them, as mountain after mountain arose, with irresistible enticements, in unprecedented states of virgin nudity, and apparent nearness, that solicited and facilitated their examinations, by the miner, to an extraordinary degree.

Under such unusually favorable circumstances, with hundreds of thousands of square miles of bed-rock uncovered, the wonder is, how little—not how much—has been discovered per ratio of the money and labor expended in this part of Nevada.

The minerals that may have existed have been since fused,

volatilized, and dispersed, excepting some few veins that laid in and near the patches of primitive rock which resisted the progress of this igneous configuration.*

These four immense fields for prospectors, still lying mostly unexplored, possess unusual advantages. The climate is unsurpassed by any other similarly extensive region in the world; so that prospectors can sleep out with impunity, and incur little risk from disease. The mountains of the interior are generally bare to the bed-rock, and invariably so in the gulches, which afford superior facilities for prompt examination.

The general elevation of the low, flat grounds, constituting the bed of an ocean's debris, washed from the mountains

* The author has traveled through most of the portions of Europe, Western Asia, and North Africa, more particularly celebrated for beauty and grandeur; but nothing in these countries can be compared to many parts of this vast interior; more particularly when displayed to view from the summit of a mountain somewhat higher than those that surround it.

The atmosphere is so clear, that two hundred miles may be seen through more distinctly than twenty miles on the sea-coasts of Northern and Western Europe; so that some scores of mountains may be seen at a glance, arising in awful sublimity, realizing all of the blues, the violets, and purples of the painter (which sometimes appear so unnatural), and affording lessons in geology never to be forgotten.

This is pre-eminently the country for illustrating all the effects produced on Earth by fire and water. It is very remarkable for the extremely rugged, disjointed, and serrated contour of the enormous quantity of irregularly washed, naked mountain flanks, which, trending northerly and southerly, like as many equi-distant, elongated, pyramidal islands, arising from an ocean; the sand flats being all of the same level and alkaline appearance, whereon nothing but the wild sage and grease-bushes grow, as successors to the past seethings and conflagrations, and the hardy precursors of future vegetation, upon the ruins of this vast cemetery, where, in these gradual uprisings from the ocean's muddy bed, fish, animals, and forests grew and petrified; now meandering rivers run but to sink into the volcanic chasms and debris of the past; a perfect panorama of geological illustration, exposing the wondrous diversities and tremendous distortions of the past and the fixed tranquility of the present.

Here may be seen at one glance a portion of an ancient ocean bed, with its fossils, on the summit of the highest mountain; on the next intervening flat, an extensive petrified forest; innumerable hot, variously mineralized alkaline springs, as miniature water volcanoes; large extinct fire and water volcanoes; sulphur mounds, alkaline flats; extensive seas of frozen lava; amidst enormous more general upheaves, equally tremendous disjunctive shifts occur, that expose every conceivable form and color to the open day of a climate that is too clear and dry for vegetable luxuriance, though most resplendent, and superlatively congenial for man.

during the gradual upheaval of this region, is now about 4,500 feet above the level of the sea, and affords natural roads for traveling in any direction from mountain to mountain; whilst their foot-hills and cañons generally supply sufficient bunch-grass and water for feeding the animals.

Another advantage is realized from the fact of animal food keeping an almost indefinite time, without being salted, even during hot weather, from the dryness and rarity of the atmosphere.

It is, moreover, free from dangerous wild beasts, and the Indians generally prefer giving civilized man a wide berth.

In mining, it will have the advantages of high reserves of mineral in the mountain veins; and for this reason, the lack of rain, and that of the general fact of a peculiar disposition of the water to sink deeper in this elevated and disjointed country, large pumping engines will seldom be required; whilst wood is generally found in sufficient quantities for hoisting, milling, and smelting of the ores. The disadvantages are their remote positions from the sea, which are already modified in one belt by the completion of the Atlantic and Pacific Railway. Other railways will in time follow, to benefit the different transverse belts through which they must pass. This, coupled with the present high rate of wages, etc., will prevent the successful mining of base minerals by companies. Gold and silver will, of course, if in quantity, overrule these difficulties, and can be mined anywhere at a profit. A class of miners have sprung into operation, on both sides of the Atlantic and Pacific Railway, that gives this matter quite a new feature, which is that of poor men, or the prospectors, working their own ledges, and forwarding the ores to a San Francisco market, saving many expenses, and thus realizing, in some cases, a satisfactory amount for their labors, on ledges or from pockets that would utterly fail in the hands of larger, more expensive and cumbrous companies, working for such profits as mines should realize, to reimburse preliminary expenditure, and yield commensurate dividends, for greater expectations.

CHAPTER IV.

THE PECULIAR KINDS OF THE PRIMITIVE AND SECONDARY ROCKS THAT CONCERN THE MINER, AS BEING MOST CONGENIAL FOR RICH VEINS; AND WHAT FORMATIONS SHOULD BE AVOIDED.

In the preceding chapter, some generally observed principles have been analogized, as to the more probable positions for the profitable plenitude of the minerals of this country; which I will now endeavor to more directly elucidate (so far as words will be understood), for the practical guidance of prospectors.

It has been previously stated that the extensive and profitable mines, throughout the whole world, have been found near the junctions of the various primitive and secondary strata; in the former, or the latter, and sometimes in the both; and although this is literally true, other collateral causes must be also present, to create the fissures, and to supply them with mineral elements, and their solvents and precipitants, or minerals will not be deposited therein.

For instance, a granitic range may traverse through and uplift, on either slope, hundreds of miles of secondary rocks, neither formation having veins; or, having them, the minerals will be insufficient to pay for their extraction; but suddenly certain changes will present indications to the eye of the miner, that will induce him to halt for more careful inspection.

Again, the prospector may travel transversely over a compact, stainless, primitive mountain, as the Sierra Nevada, from the eastern verge of the Californian system of auriferous veins, without seeing a lode, until he reaches the appropriate formations on its eastern slope, as at Virginia and Carson Cities.

The questions now arise, as to what additional appear-

ances, modifications, and transformations, should be sought by the explorer, in these strata? In this connection, there are five valuable premonitory indications; the first being what will be better understood as *broken ground*, or partial disruption, disintegration, and decomposition of the stratum; where frequent crumplings, distortions, and fractures, show that sufficient force has been in action for the creation of veins, and shattering the surrounding bed-rock, for the free percolations of mineral waters, as well as greater freedom for the decompositions of those rocks which may contain their precipitants.

The centres of extensive primitive ranges are naturally very compact, and water-tight; and, consequently, no veins or minerals are found in such remote positions.

Secondly, it is advantageous to, and characteristic of, mineralized districts, when reefs of variously compounded rocks interlace and distort the primitive, transition, and secondary formations, by curvatures, "heaves," and "slides"; and the more so, when they give evidence of different ages of such disruptions.

Thirdly, for gold it is an invariably favorable sign, as it is sometimes for silver; when the upheaved talcose, micaceous, and argillaceous clay slates are much folded and tilted, even to the vertical, for long distances, from their originally horizontal position, and when the *very lowest foot-hills* and oceanward flats show the presence of the oldest fossils of salt-water shells.

Fourthly, a moderate amount of the stains from the oxide of iron, generally disseminated throughout the stratum, and mixed with the sulphurets of iron in and near the vein, are excellent guarantees for the presence of nearly all of the metals, and metallic minerals; many of which are never found out of its company.

And, lastly, that which will be almost impossible to describe, although as much heeded by the miner as the soil is by the farmer, consisting of a peculiarly congenial and prolific stratum, and a correspondingly generous, maternal nature of the quartz, from the veins, as well as a fresh, pregnant ripeness of the minerals themselves, as if but just

arrived at puberty of strength, ere they were again dispersed by Nature's solvents.

These indications are designated by miners "kindly ground," "sugary spar," and "rotten ripe"; the reverse being "ugly unkindly ground," "hungry country spar," and "dried up ore": each particular meaning being well understood by the miners, and acted on during their practical lives, to assist them in arriving at the more profitable sections of veins, during their speculative tribute contracts.

To describe the rocks which should be avoided, when searching for minerals, is an easy task. In the first place, it is unadvisable to go far away from the junctions of the transition or secondary with the primitive rocks, or into the interior of the more igneous volcanic regions.

Secondly, all extensive regions of *porous* volcanic bed-rock should be despised, for deficiency of veins, and paucity of minerals; for, although it may be said that the *native copper* mines of Lake Superior are in amygdaloid, this is a solitary exception, where volcanic fire may have interfused the minerals into metals that existed in pockets or veins prior to such invasion; be this so, or not, I know of no other instance where *metallic copper* is found in veins that are entirely *destitute* of the *minerals* of *copper;* and therefore it does not conflict with these rules for minerals.

Thirdly, the modern carbonates of lime and magnesia, and clay slates, that enclose well defined shells, seldom produce veins with sufficient mineral to pay for extraction; excepting rare pockets of silver, and the minerals, lead, iron, coals, etc.

Fourthly, avoid too close proximity to extensive deposits of mineral, the property of others, as the largest bunch has its limits, and sufficient space must intervene for the accumulations of the mineral elements, or precipitants, before another considerable body of ore can be deposited; it is generally better to go a few hundred feet, and often miles, away from, than to mine in close proximity thereto; the history of great discoveries have too frequently shown a large debit balance to such districts from this practice.

And, lastly, to guard yourself from becoming too much attached to your own ledge, mine, or district, by discarding sanguinity, and searching for defects and poverty; never for-

getting these patented facts: that deposits fail much oftener than they continue rich, and that very many blanks must be drawn for one prize.

As an illustration for exposing the folly that minerals are equally disseminated, or that riches must generally extend because a mine or two has been profitably worked in a district, it may be interesting to the reader to know that the County of Cornwall, England, is altogether but a mere speck, forming an isosceles triangle, on a base of about forty miles, and about one hundred miles from base to apex. Small as it is, as a whole, not much more than one-hundredth part has been proven to be profitably mineralized, which is not in one particular district, but lies, as it were, in some few small spots; the intervening ninety-nine parts being, so far as known—after a thousand years mining for minerals, that for many generations almost supplied the world—as worthless as any other unmineralized country. The rich districts flank and surround small but genuine granite hills, or are near thereto in basins of "killas," which is a very peculiar kind of rotten, disjointed, and but slightly stratified argillaceous clay slate, that is of very different appearance to the outlying, unmetalliferous, and more stratified clay slates. These districts, commencing at the apex, are the St. Just, St. Ives, Lelant, Marazion, Huel Vor, Wendron, Gwinear, Cairn Brea, Gwennap, St. Agnes, Chiverton, St. Austle, Fowey Consols, Bodmin, Liskeard, and Callington.

It should be remembered that even these small and closely situated districts have some individual peculiarities of formation and character of strata, indicative matrices, and mode of occurrence of the minerals in relative positions.

CHAPTER V.

THE LOCATOR'S PRELIMINARY EXPOSITION OF THE GENERAL FEATURES OF A VEIN, SO AS TO ASCERTAIN ITS APPROXIMATE VALUE.

After the location or preëmption of a vein, it is imperatively necessary that a certain locally regulated amount of work must be performed, within a specified time, prior to its being placed on record, so as to secure legal possession; and this work should be executed for the more useful purposes of ascertaining the definition and value of a ledge: such has not been the practice, for it has generally consisted of an open cutting through the softest place, so that the required number of cubic feet could be excavated in the softer "bed-rock," with the least possible trouble to the discoverer, ignoring this or any other useful purpose.

Had the law demanded that the first columns for marking the discovery should be superseded by other columns of rock, broken from the ledge itself, within the usually specified time (for the excavation of cubic feet), this would at the same time accomplish an actual examination of the vein, at one, or on many points, which could be still farther systematized by taking the matrix vein stone from a hundred places all over the back of the lode, and, after breaking ten times as many pieces from all the corners of each of the monumental stones, it might be treated as follows for examination and value:

Crush all the small pieces thus obtained between two flat, hard stones, to the size of peas, and after collecting all the debris, coarse and fine, and mixing them as intimately as possible, take therefrom two portions of about one pound each; the one pulverize as fine as your convenience will allow, and treat by water in your prospecting pan, baking

dish, or horn spoon, for gold, or for the nature, quality or quantity of the heavy residue; if this test is found to be encouraging, forward the other portion to a professional assayer, to ascertain its value.

This will be more fully and correctly described in Part III, Chapters I and III, for those having the portable prospector's "Wee Pet" assaying machine, to finish the assay.

The most absurd and frequent practice of single stone assays cannot be too severely ridiculed; for it would be just as reasonable for a geologist to land on a strange coast, and pronounce the whole country similar to what he saw beneath his feet; or as correct for a burglar to enter a general hardware store, during darkness, and, bringing the first thing he handled to the light, to say that the whole store was stocked with pestles and mortars.

This more systematic and rigidly correct method for averaging its quality may expose the ungarnished truth, and damp your ardor; but it need not debar you, if you will still work the wires of deception, from the diabolical and too prevalent practice of selecting the best stones that you can find in the more favored parts of the vein for city exposure, to directly mislead *them*, and to draw the finger of scorn, ultimate ruin, and disgrace, on *yourselves*, and on mining.

It frequently happens that ledges disappear under the soil or surface debris; and, when such hides the vein, it may be found by what has been called in Cornwall "costeaning," which is simply a search for the back of the lode, by a right-angled cutting or a few transverse pits or shallow shafts, that attain the "fast," or bed-rock, and sometimes the lode or its relics, unless it happens to lie between these excavations, when it is discovered by a level driven partially in the bed-rock from one to the other shaft. In the absence of better proof for its position, a straight line may be drawn on its bearing where last seen, and suitable allowances made for local contour and influence of the enclosing stratum or strata. For example, we will suppose this direction line runs due south over descending ground, and the vein dips east, or to the left, at 45°. It will be only necessary, in such a case, to take the difference of altitude of the known and unknown parts on this side of the vein, and to measure towards the

east, or left hand, its gain from such dip in that direction, which, in this case, would be exactly as much as the fall, or difference of height, of the two places.

This will also apply for rising ground, by reversing the measurement to the right.

"Float stones" frequently serve to direct the prospector, which, being almost invariably found on the lower side of the vein, indicate a higher position for the croppings of the lode.

In some positions, water springs may be also advantageously noticed, to facilitate in finding the exact position of emergence.

SECTION III.

ASSAYING AND DISCRIMINATION.

CHAPTER I.

SYSTEMATIC PREPARATION OF THE SAMPLE TO OBTAIN AVERAGE EQUALITY FOR DISCRIMINATION OR ASSAY.

To take a sample from a ledge or parcel of ore that shall fairly represent its average, and prepare it so that the lesser quantity weighed for assaying shall be sufficiently homogeneous for a correct ratio of value, is really the most important part of mining, and should be conducted with vigilant care, as herein lies the preliminary test for the succeeding profit or loss by mining or reduction.

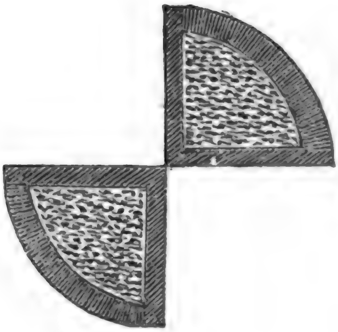
The retrospection of the resultant losses from disregard or ignorance of this subject is monstrously ruinous, as it has injured mining so much that many years must elapse before even legitimate properties will be recognized by capitalists. Mills and smelting works should be used for realizing profits from established riches, and not as enormously expensive assaying works, on doubtful, unexamined ledges.

In the last chapter of Section I, the prospector had taken a careful average from his ledge, by breaking rock from a thousand places throughout its length and breadth, which, after it had been broken still smaller, to the size of peas, was carefully collected and thoroughly mixed together.

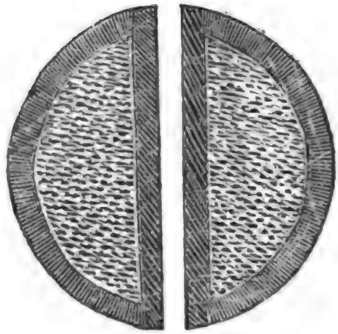
We will now receive this sample from him, and manipulate for an example, in a manner that has not been described in books, nor so fully practiced by assayers; but which you

will find better adapted for obtaining correct results than any other method.

Cut 10.



Cut 11.



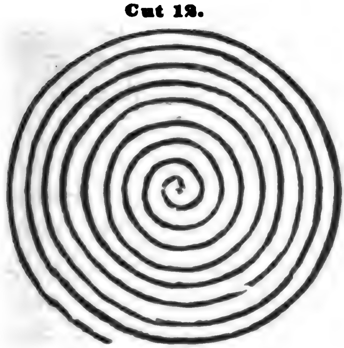
The Cornish systems of quartering the parcel (Cut 10), or cutting a gang-way through the centre (Cut 11), although sufficiently near for concentrated base minerals, will not approach to it in accuracy, for gold and silver. The chief causes of error being the unequal distribution of coarse and fine, or light and heavy, which carry a more or less difference of quality, by taking irregular positions from the centre outwards, or from the top to the bottom of the pile, and by lying nearer the perimeter of the quarters, or falling unequally in the gang-way, it gives a less average than it should for the miner, because the least friable pieces, being consequently larger, fall to the bottom of the cut, or to the periphery of the pile, and, being more quartzose, contain less mineral than the soft and more friable minerals; it is, moreover, less simple than the halfing mode (to be described), doubles the length of the lines of error, and lacks the additional guarantees of the repeated mixings, trailings, and dividings, during its more systematic reduction. The monopolizing and exacting smelters are fully aware of this, but take all advantages from the unresisting miners.

If you wish to have a correct average, or expect the certificates from the different assayers to agree, this must be performed faithfully as follows:

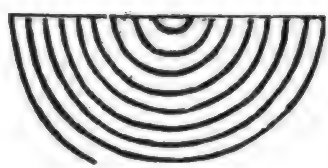
Spread this partially equalized ore over a clean spot, to the shape of an inverted prospector's pan, draw a diameter line—or, still better, a large sheet of iron or piece of plank—

through the centre, and take the whole of the one-half, coarse and fine, therefrom, which remix by repeatedly turning it over; shape and divide as before, until the sample is reduced to ten pounds. Pass the whole of this ten pounds on to a clean newspaper, sheet of glazed paper, prospecting pan, or plate, and again mix as intimately as possible, by alternately *collecting it several times to the centre*, and *redistributing it* with the finger, *by trailing a watch-spring path from the centre outwards* (as shown by Cut 12); again divide this

Cut 12.



Cut 13.



ten pounds by laying some thin, vertical partition, as a hand-saw's back, or a table-knife, through its diameter line down to the very bottom of the sample (as Cut 13), and sweep, with this knife, or saw, and a hare's foot, or brush, the whole of the coarse and fine of the nearer half away, scrupulously clean.

Pulverize the remaining five pounds to the maximum size of rice, *without sifting*, and, after mixing, dispersing, and dividing, thrice, as previously described, pulverize and sift the remaining ten ounces with the finest gauze sieve, such as that supplied with the assaying machine, carefully noting its upper side for flattened disks of the metals gold, copper, etc., which, if found, must be weighed to ascertain their percentages to the whole ten ounces, or any other total quantity, and added to that resulting from the one ounce or other weight taken for assay from what did pass through the sieve.

In gold and copper assays, this occurs frequently, and sometimes in silver; but, with the latter, a tough metalliferous chloride often flattens into treacherous cakes, which, by

not passing through the sieve, vitiates the resultant assay from such an ore, unless guarded against, and also separately valued; which, in the case of silver, must be also smelted and refined. Lastly, invert the sieve on pile.

If no metal is present, or extreme accuracy is unnecessary, about two and one-half pounds may be taken from many parts of the large heap, instead of the ten pounds, and otherwise treated as directed until it is reduced to its similar ratio of two and one-half ounces.

This last, after sifting it through the fine sieve, must be remixed, distributed and halfed as before; and, if the ore is infusible or refractory, this should be further pulverized under the pestle, by rubbing, to an impalpable powder, when, after being again mixed as before, it is ready for weighing the quantity for the assay.

This mixing, after pulverization or sifting, is imperatively necessary, as the pestle as well as the sieve passes the more friable portions first, thus rendering the bottom of the pile the richer.

Tapping or jostling, which causes the heavier and richer portions to settle to the bottom, should also be carefully avoided until the sample is weighed. It will be seen that this method of cutting off the one-half of such intimately mixed sample, approaches as close as possible to mathematical accuracy, as there is really no line of error, as the absolute half of a similar pile is thus retained.

It has been the English practice to ascertain the water-weight, by drying a weighed portion at 212°, and taking the assay from the dried sample, or allowing for it by adding as much as will equal it when weighing for the assay, which, however, has not yet been done in this country.

Should you require to know this, dry one hundred grains of the ore in a plate, saucer, or some clean vessel, placed, *as a lid*, over a *tea-kettle*, or *coffee-pot*, full of boiling water; and ascertain its percentage of loss on re-weighing the dried residue, by subtraction.

CHAPTER II.

DESCRIPTION AND GENERAL ADVANTAGES OF THE PORTABLE "WEE PET" ASSAYING MACHINE.

The above is the name given to a machine that has been devised for the benefit of the mining public generally, but which is more especially valuable for the prospectors of this great and virgin mining country. Beyond the regions that have been and are now being explored, primitive mountains arise, uplifting their declivities of secondary strata, looming in the distance to entice forward the more adventurous, where, if the historical analogy of the mining world should be their guide, many interesting and legitimate fields remain unexplored.

It has been correctly observed by some of the best and most practical authors on mineralogy, that however experienced a miner may be in the visual discrimination of gold and silver ores, he is often deceived in his judgment of the value of rock; and this applies to ores of much greater value than such as will pay for mining and reduction, as the mixed ores of volcanic regions, and the antimonial, copper, lead and iron ores, where the precious metals are completely concealed. These authors also commend the common mouth blow-pipe, as an inseparable companion of those requiring greater certainty in mining operations, as well for quantitative as for qualitative assaying of most minerals, but more particularly for silver, which it performs with surprising accuracy. Its powers are truly wonderful; but proper instruction, great practice, and expensive tools, are imperatively necessary, as well as the peculiar qualifications for handling, manipulating, smelting and cupeling an assay of but one grain, and where the resulting button is so small that the one-thousandth of a grain would be but $37.70, and the one-ten-thousandth $3.77 per

ton of 2,000 pounds. I know of no other single chemical operation that requires more knowledge, practice, care and watchfulness, to obtain exact results. These, with many other difficulties to which there is no "royal road," and the greater need for preparing a correct homogeneous sample, to render the sample of one grain the correct representative quality or ratio for the ton, have and will prevent its general application.

The crucible and scorifier require a large furnace and muffle, with numerous tools, etc. They are slower in action, and consume a large quantity of expensive fuel, which must be prepared, or carried from place to place, as required; so it is far worse than the former, as all are thus prohibited from its use.

The humid or chemical methods demand many costly and fragile tools, with dangerous liquids, an especial education, and general knowledge, or they will be mere useless things.

Thus, the explorers have been roaming ignorantly, where knowledge was most desirable, and the legion of mining companies have forwarded mills, at a cost of from $20,000 to $100,000, to assay an average from their ledges, to prove most disastrously to them that but *one* in fifty are valuable; and millions of tons have been reduced that would not pay, by either milling or smelting, for want of an easy means to ascertain its value.

In view of the immense demands of this country, and knowing the insufficient methods in use by miners, millers and smelters, *when required for prospecting*, as well as the first and most important difficulties of my students in their manipulations with the common mouth blow-pipe, I have contrived this machine to overcome all the real obstacles appertaining thereto; such as a continuous blast, preparing and fluxing the assay, shaping its holder and charcoal support, cupels, etc., as well as holding and varying its position during the smelting, cupeling and refining operations; and ascertaining by tables, which lie under and on either side of the balanced button, as it rests on the beam, the value in dollars per ton, or its one-thousandth fine, for silver and gold, and percentage in base metal assays, all being read at sight, without calculation. This weighing is much facilitated by

taking the differences of large weights, instead of using the ordinary minute weights, riders, etc., of assayers by other methods. In addition to this, I have two diverging metallic straight-edges, laid on a bed, so that the one end may represent \$160, and the other \$10; the intermediate space being graduated from \$10 to \$160, and wherever the button *jams*, its value is recorded on the scale. There is also a hole at the end of this plate, of such size that a \$40 button will just drop through, when the explorer may proceed in his questings for other ledges, as this is not sufficiently rich to pay for mining and milling of silver ores in the interior.

By these combinations, the apparatus has surpassed my expectations, as to the quantity of ore it will reduce. I have operated successfully on twenty grains, although it is arranged for ten grains to the public; and I claim that with these arrangements and combination of automatic movements and calculator, a man of ordinary skill can make an assay with this apparatus anywhere, even on the ground, sufficiently near for all the practical working purposes of those to whom I have dedicated it, and in less time and at one-tenth of the cost of any other method. So portable is the apparatus, that the whole machine, with fluxes, tools and scales (weighing less than seven pounds), is packed for conveyance within a cube of five and one-half inches. The price of the whole is \$100, accompanied by a book of instructions for assaying gold, silver, copper, and lead. Those buying a machine in the City of San Francisco, having the further advantage of seeing an assay made with it by its inventor and patentee.

The machine is also most conveniently fitted for the general purposes of the laboratory, as shown by the illustrations, as roasting, drying, crucible fusion, and ignition: fusion *per se*, or with an alkaline carbonate, on charcoal; of ten or twenty grains: for testing with tubes, flame, flux re-agents, in forceps, or on wire; and to dry, sublime, evaporate, boil, distil, filter, etc., etc.

For the purpose of fusing very stubborn metals or minerals, it may be rendered very much more effective, by introducing a separate jet of oxygen, hydrogen, or oxy-hydrogen gases, formed simultaneously, and ignited by the ordinary flames, at the moment of exhalation; or a reservoir of alcohol may

be placed beyond the assay, which, being warmed by the waste heat from the departing flames, would force its jet of alcoholic vapor through a similarly placed central nozzle, and, by supplying this auxiliary combustible, the heat would also be thus intensified.

The machine has been lucidly described by the *Daily Alta California*, of the 29th October, 1869, when reviewing the articles on exhibition at the Mechanics' Institute Fair, where the apparatus was awarded, by the Examining Committee of Philosophical Instruments, a gold medal, accompanied by the following encomium:

"FIRST PREMIUM GOLD MEDAL TO J. S. PHILLIPS, FOR 'PORTABLE ASSAYING MACHINE.'

"*For convenience in use and accuracy in performance, we esteem this little machine as of the greatest utility to the mining prospector, and well calculated to relieve our mining interests of the uncertainty hitherto attending their development.*"

The *Daily Alta California* says:

"This is an automatic assayer, very curious, intricate and compact in construction, placed on exhibition by J. S. Phillips, M. E., whose patent bears date September 7th, 1869. It is more especially contrived for the use of the prospector, by superseding the educational operations with suitable mechanisms; the whole work of assaying is so much simplified, that a novice in the art can learn to make his own assays after some three hours' tuition. It is extremely light and portable, yet strong and efficient, being all that can be desired for the practical purposes of those to whom it has been dedicated; and, as such, it is pre-eminently adapted, and the only really effective tool for the general itinerant purposes of the mining community. The ordinary 'mouth blow-pipe' is its only rival, and with which it may be favorably compared. That, having but one exposed flame, operates but on one grain. This, having several concentrating flames, and being supported by and covered with charcoal, and further aided by nineteen patented claims, treats from ten to twenty grains. That, but one man in the million can use for assay. This, the million can learn to use in a few hours. That, must have many tools, a very delicate, expensive and cumbrous balance, that, turning with the ten-thousandths of a grain ($3.77 per ton), requires considerable practice, care, nicety and calculation for even this margin of value, as well as a table and close room for its use. This, contains the complete apparatus, with all necessary tools, re-agents and fluxes in a cube of five inches for the prospector, or five and a half inches for the miller, weighing from six to seven and a half pounds. The refined button from the assay is merely balanced on a grooved lever, and its value in dollars per ton, and thousandths fine for gold and silver, and percentage of base metals, read at sight underneath or opposite to where it lies. Small globules are also measured between two metallic diverging straight edges, resting on a bed plate, and

their value in dollars per ton read on either side for gold and silver. A small funnel-mouthed hole is also drilled in one end of this plate, so gauged that buttons of insufficient quantity for mining and milling shall pass through, thus promptly indicating their worthlessness, and saving the time required for balancing. A good weighing and calculating balance is supplied to those who prefer it at $20 extra, for commercial purposes, to be used within the same space of this machine. In that (and all other methods), the assay is made with difficulty on the mountain or open ground, and the mouth, eyes and hands are entirely engaged for some twenty-five minutes during the smelting and cupellation. In this, the assay may be made during conversation, the hands being at liberty for occasional purposes, and the slag may be stirred with an iron wire, to ensure faithful performance. The cost of making an assay is about five cents."

The *Golden Era* describes it as follows:

"The most important and advantageous novelties of this machine, nineteen of which have been secured by patent right, are the following: It is extremely light and portable, yet strong and efficient. Its automatic facilities for preparing, weighing and fluxing the sample, as well as for blowing, supporting, smelting, cupelling, and reading its value in dollars per ton, etc., etc., under the balanced refined button, are so well contrived that a man may really become an assayer, for practical purposes, in a few hours. The pulverized sample, being well mixed, is ground in the mortar to an impalpable powder, and ten grains are weighed in the scoop at the back of machine, and, after being fluxed, it is transferred to a previously fluxed and pasted paper cartridge, which is taken between the thumb and finger, shaken to mix, folded down, and placed in a suitably shaped charcoal or moulded composition support, into the stemmed cup as seen in front; next, either one piece of charcoal, or a small furnace containing several, is suspended by the four elastic fingers over the assay, and the flames are blown from four olive oil lamps to concentrate their individually intense heat into this close furnace, by an occasional full breath from the uneducated lungs; thus operating promptly and successfully on ten times as much as the ordinary blow-pipe can treat when conducted by a long practiced expert. This smelting operation lasts from ten to fifteen minutes, during which time the operator can converse, and is otherwise perfectly at liberty for occasional purposes, as turning, inclining or shifting the position of the assay; by handling the non-conducting cork on the cup-stem, it can be elevated or depressed by the screw, or transferred to all other self-sustaining positions by the very appropriate motions of spring levers. The rich lead button thus produced is cleaned and cupelled in a similar manner on bone ash supports (prepared in two ways by suitable tools: the one naked, and the other encased in metal); and this refined button is merely moved to balance on the longer end of the calculating lever, when *one* of ten numbered weights is placed in the pan that is suspended at the other end; when thus balanced, the value is read beneath, either in dollars per ton or thousandths fine of gold and silver, and the percentage of base metal assays in the column having the number of the weight at its head. This is quite an institution in itself, in connection with which, however, there is one peculiarity, which, as an experienced assayer observed, "prospectors will never fully value"; that is, the ten grains weight, or the weight of the assay, is used to balance the main lever only, so that, by substi-

tuting ore, the sample is weighed without any weight; and again, after first balancing with this, and substituting a numbered weight, the *difference* will, by being made equal to a real minute weight, answer instead, and therefore no weight is required that is smaller than this balance of ten grains."

From the *Scientific Press:*

"An assaying apparatus, which could be carried about easily and be of practical use in the field, has long been a desideratum. The blow-pipe, with its delicate tools, is suitable merely for the laboratory, and the common assaying furnace is too cumbrous to be of any general application. We know of no device, hitherto, which has combined the necessary qualities of compactness, durability, and requisite accuracy. Last September, however, Mr. J. S. Phillips, a mining engineer of San Francisco, who has had long experience in assaying, both in the laboratory and in the field, patented an apparatus which, he claims, satisfies all these demands, and can be readily used by the prospector, who needs but a few hours' instruction to be able to assay his rock, wherever he may find it, at a cost of but a few cents. * * * One great object of this invention was to put into the hands of the uneducated prospector a device which would be automatically so complete that the operator could obtain proper results with the need only of a few hours' instruction, and the application of a little care. Hence, it is made as simple as possible; the weights and similar articles are of a size to be readily handled by fingers used to the pick, and are marked so as to prevent the possibility of mistake; and the results of the assay are marked down before the eye, requiring only the ability to read on the part of the assayer. * * * With great ingenuity, all is made to go into a very small space, including the necessary blow-pipe fluxes and re-agents. * * * Great ingenuity is displayed by Mr. Phillips in many ways: for the purpose of holding the assay automatically, to adapt it to the use of unskilled persons, to weigh and obtain the results at sight, to secure portability, etc. * * * We have seen assays made by Mr. Phillips with his machine, in a very expeditious and satisfactory manner."

The apparatus has been but partially detailed here, as it will be more minutely described in the instructions contained in the chapters for discriminating and assaying the various minerals.

CHAPTER III.

NEW METHODS FOR THE EXAMINATION AND ASSAY OF ORES BY WATER-WASHED CONCENTRATIONS; SOMETIMES PERFECTED BY ACID SOLUTIONS OR MERCURY, AND COMPLETED WHEN NECESSARY BY CRUCIBLE, SCORIFIER, OR MACHINE; AFTER ROASTING, BY FLUXED FUSION OF THE HEAVY RESIDUE.

The application of water for the discrimination and assay of minerals and metals, is far more appropriate for the daily requirements of the miner, analyst and assayer, than is generally believed; and, when systematized, it may be made a wonderful auxiliary in many ways; it possesses the still greater advantages of being within the reach of all, requiring no other tools than are found in mining camps, and but little instruction; performing, as it does, at a trifling cost, more actual work in less time than any other method, excepting only the chemical analysis, that must be executed in the laboratory by the educated expert, at considerable expense of money and time.

To the blow-pipist and chemist it renders an invaluably prompt anterior and posterior means for qualitative-quantitative approximation, selection, separation, or concentration; especially for preliminary examination previous to more elaborate treatment.

In experienced hands, many samples that the miner has to beneficiate can be actually assayed more correctly by water than by fire; and ordinary amateurs may realize its full value for many practical purposes: as free gold, oxide of tin, the sulphurets of copper and lead, etc., etc., when they are not associated with other minerals, or very heavy gangues; others can be assayed by water, that cannot be easily assayed by fire, as sulphuret of zinc, sulphuret of antimony, oxide of manganese, iron, etc., etc.

It has, however, three disadvantages, which to some extent qualifies its quantitative usefulness: it cannot be used for silver, and for the other ores it demands that the operator shall be fully acquainted with visual discrimination of such when in a powdered state; and that the sample must be free from that confusion so frequent in volcanic regions. When the heavy residue is treated by fluxed fusion with the crucible or machine, these latter more refractory ores will be fully subdued for practical purposes, into the necessary condition.

For such men it will be, therefore, most advantageous, as will appear hereafter, for examination and assaying.

For example: Take a hundred grains, or parts, from a complicated pulverized sample, prepared and dried at 212°, as directed in Chapter I, Section III, that contains one or more of the following substances: as free gold, metallic copper, metallic iron (from the mortar), oxide of tin, sulphuret of iron, red oxide of copper, sulphuret of lead, gray sulphuret of copper, yellow sulphuret of copper, sulphuret of zinc, and oxide of iron, associated with their matrices of quartz, clays, feldspars, carbonates of lime or magnesia, etc., or others of similar specific gravities and friability. Take three porcelain dishes, as used by the chemist, or three ordinary enamelled soup-basins, plates, tea-saucers, or cups, as found in the mines, or a good vanning shovel, prospecting pan, horn, or horn spoon, as used in the mills and mines, with two of either of the others, or any suitable and clean vessels that you can obtain or may prefer: into the first place the one hundred grains or parts from the dried sample, which cover with about ten times its volume of water, and stir the whole for five minutes; then, after allowing it to remain sufficiently long for the water to thoroughly permeate and dissolve the soluble portions from the mass, which may be facilitated by warmth, carefully pour or filter this liquid into one of the other vessels for separate examination by re-agents, etc., thus easily separating these that are soluble from those that remain insoluble in water.

It may be sometimes necessary, for your purposes, to ascertain this percentage, by transferring it with a camel-hair brush, after it has been dried at 212°, to the scale pan, and deducting this from the original one hundred grains. Replace

the sample in the concentrator, and, after covering it with thrice its volume of clean water, strongly agitate the vessel by a properly varied circular and reciprocating motion, and pour off the water somewhat speedily, but very carefully, during a slower transverse oscillation of the water, into the third vessel, re-pulverize with the pestle, by rubbing, the remaining sample in the water; shake, and pour as before, and repeat this four-fold process until the lighter and more friable debris has departed, and the quartz approaches the margin.

This third receptacle will contain most of the feldspars, clays, lime, and magnesia, which will soon settle to the bottom, and, after the water has been poured off, can be examined by means that will be described in a future chapter: the oxide of iron will also pass over in this stage, which will be indicated by the redness of the water, and can be chemically tested; the other constitutional forms of iron can be now seen in the residue. The remaining quartz and minerals can be dried at 212°, and weighed for percentage.

For the further treatment of the heavy residuum, unless the operator is already skilled in the use of the vanning shovel, horn, or horn spoon, he had better rely on the slow oscillation of the water, transversely to the escapement margin, and take more time for ridding the minerals from the heavy gangue, whilst adopting the following precautions: Supposing the instrument is a porcelain dish, tea-cup, saucer, or soup-bowl; it will be better to have sufficient water in the the third dish, that contains the earths (which should be removed, if you would test them separately), so as to enable the operator to alternately keep the side of the concentrator slightly in or out of the water, during the slow sideling sway of the water over the minerals and escaping quartz; at this stage, great care must be also taken in giving the proper angle, so that nothing but gangue shall escape; and, towards the finish, a little direct mechanical means may assist these particles over, or arrest the more forward minerals, that might otherwise pass away.

This being completed, re-concentrate this third dish in a similar manner, to obtain any mineral that might have passed over in the first washing, so that it may be added to the first concentration, which must be dried and weighed. Now, as

the first dried sample of one hundred grains contained no water-weight, the second similarly dried sample, if weighed, will show the percentage of the remaining insoluble portion, and, when taken from the original weight, will leave the percentage of what was soluble in water.

The third dried weighing will give the percentage of quartz, compact feldspars, and minerals; which, being deducted from the second, will represent the lighter and more friable oxide of iron, clays, and carbonates of lime and magnesia. The fourth and last, taken from the third, equals the quartz, etc., and is the weight and percentage of the metals and ores, which may be still further separated by magnet and forceps, assisted by a lens, into different lots of metals and metallic minerals; after being weighed, the minerals may be also calculated for their metallic contents.

If more than one of the metals or metallic minerals are present, an experienced hand, with great care, assisted by the magnet or magnetized knife-blade, and an occasional touch, with a few repetitions, if necessary, from vessel to vessel, can often separate each, by causing them to successively follow as they are named in the example; and the amateur, by drying and spreading the heavy and closely concentrated residue over a clean plate, can examine with a magnifying glass, and, if necessary, place them with a forceps into as many different heaps for quantitative as well as qualitative assay; by weighing and calculating their percentages from their equivalent proportions by multiplying each individual weight by the following numbers, and dividing by 100; or, better still, by moving the multiplier's decimal point two figures to the left hand:

The oxide of tin contains 78.38 per cent. of metal.

The bi-sulphuret of iron contains 46.7 per cent. of metal.

The red oxide of copper contains 88.8 per cent. of metal.

The sulphuret of lead contains 86.55 per cent. of metal.

The gray sulphuret of copper contains 38.42 per cent. of metal.

The yellow sulphuret of copper contains 34.6 per cent. of metal.

The brown sulphuret of zinc contains 66.7 per cent. of metal.

Thus, weighing many of Nature's insoluble precipitations as they are found, instead of decomposing them in the laboratory of the chemist, by difficult, far-fetched and expensive means, but for re discrimination, separation, and precipitation to frequently similar compositions.

This is, however, a complicated case by any method, either for analysis or assay, and it seldom happens that the sample contains so many kinds; the object of such an example is to expose the general principles of this ready means that the *chemically* uneducated prospector and miner has unconsciously at his fingers' ends, in this exacting practical test; that at least affords a parallel for the general waste of the large scale, by water-washing and milling treatments.

It also illustrates the general constitution, comparative qualities and quantities of the sample, which the most experienced analyst and assayer would least despise, as it opens a volume of useful hints, that enables him to treat it precisely as it should be treated; for, discarding nine-tenths of the time occupied in this case, by hastening through the intermediate stages, he arrives at the end in ten minutes, and is thus informed that, for the assay of gold, it is not all free, but, being partly imprisoned in sulphurets of iron, it demands a preliminary roasting, so that the whole of the gold may be realized. For copper, he sees that metallic nuggets will cause a treacherous, varying result, unless the upper side of the sieve has been well attended to during the sifting of a large quantity, and separately calculated for, after addition to the result from mineral assay: he sees, also, that the yellow and gray sulphurets must be roasted, and the first metallic button from such an one must have an additional refining, or an excess of copper will be recorded. It informs him that the fire assay for tin would produce but an unfinished, refractory alloy; and, consequently, the assay must be accomplished by some other method, or as follows:

First, complete the assay of this staniferous button, as just obtained, by chemical analysis.

Secondly, dissolve the one part, of one hundred grains, in three parts of hydro-chloric acid, one part of nitric acid, and one part of water, gently boiled for about one hour, in some position where the fumes may pass away; pour off this solu-

tion, which carries the gold, copper, lead, and iron, and after washing the oxide of tin (which still remains unaffected) with water, assay it by crucible or machine, as will be described in its proper place, at Chapter XI, Section III.

It is a somewhat singular and most advantageous fact that the sulphurets of lead and antimony do not associate with tin, which saves much annoyance; for, being of similar specific gravity, and very fusible, they would be so obstinately associated, that not only water would fail to separate them, but *roasting* could not be more advantageously resorted to, for *after* separation by water, as is the case with the sulphurets and arseniurets of iron.

Thirdly, re-pulverize, and further concentrate, until nothing but the metallic copper, sulphuret of iron and oxide of tin remain; pick out the gold and copper, with the forceps; roast the remainder at a red heat, pulverize, and wash until the water ceases to be colored red, and, the oxide of tin appearing clean, can be also reduced by either of the fire methods.

Fourthly, dry this concentrated oxide at 212°, weigh, and calculate its percentage, by multiplying it by 78.38, and dividing by 100.

Thus, if the weight of oxide obtained amounted to ten grains, the formula and result will stand thus: $\frac{10 \times 78.38}{100} = 7.83$ per cent. metallic tin; or, $10x\ .7838 = 7.83$.

These, second third and fourth. when accurately conducted, are perfectly reliable, and millions of pounds sterling have been paid for ores that have been assayed less correctly.

This tin oxide is unaffected by the pestle, water, acids, or unfluxed red-hot roasting; and, consequently, the roasting, pulverizations, and washings, greatly facilitate to entirely rid it from all the other minerals with which it is associated, excepting only the rare tungstate of iron (wolfram); the injurious effects of which, however, has been controlled in the second and third by acids and fire, as the last can be by the addition of a few drops of hydro-chloric (muriatic) acid, towards the latter end of the last washing, before it is dried for weighing.

For lead, in this sample, he finds no correct fire method for its assay, etc., etc., and therefore chemical means must be

resorted to; or the lead must be extracted therefrom with the forceps, and calculated from its percentage of metal, or passed into a fluxed fusion to the metallic state. In short, the whole components of the sample are so laid bare for such purposes, that, with a good lens, he can see the variously formed and colored metals and minerals, with their relative proportions and constitutional natures, as distinctly as he would as many flowers in a garden; which can be separately examined by the blow-pipe, or wet re-agents, for further collateral satisfaction, when deemed necessary.

Gold may also be not only tested, but actually assayed most promptly, by this mode, either in free condition, or parted from its heavy residue by acid, dried, and weighed; or amalgamated with mercury, and smelted by crucible, scorifier, or machine, into button; as fully described in Chapter VII, Section III.

The blow-pipe, wonderfully prompt and effective as it undoubtedly is, in the hands of the expert practical, for discrimination, often stops far short in the qualitative-quantitative examination of the more useful metallic minerals worked by the miner, thus so readily afforded by this less studied and preëminently practical means; to which the best blowpipist may ofttimes resort for valuable assistance, both before and after his fire testings.

CHAPTER IV.

THE MODES FOR DISCRIMINATION BY ORDINARY BLOW-PIPE, OR ASSAYING MACHINE, ASSISTED AT TIMES BY DRY AND WET TESTS, OF SUCH OF THE METALS, METALLIC MINERALS, AND EARTHS, WITH THEIR COMBINATIONS, THAT SHOULD BE KNOWN BY THE EXPLORER, MINER, MILLER, SMELTER, ASSAYER, AND METALLURGIST.

The following methods for ascertaining the presence of the useful minerals were written to assist the practical man, by comparatively simple means, in recognizing the kinds, and comparative quantities, when sufficient is contained in an ore for profitable purposes, rather than for the more accurate analysis; and I have therefore deviated, in many ways, from the stereotyped records of books for such men's "living present," daily requirements, in a business for which their education had not been intentionally adapted.

If they have desire, time, opportunity, energy, and perseverance, before breast, these rudimentary examples will not deter, but encourage them to prosecute the studies of the more general features, in the many elaborately systematic works on this particularly interesting subject, that have been published in the leading languages, since the days of the immortalized Berzelius, and the other enlightened practicals of Sweden, to whom the world has been principally indebted, for the wonderfully prompt and numerous reactions obtained from the useful blow-pipe.

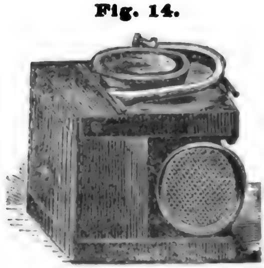
Favoring this system, the assaying machine was contrived for enabling the unpracticed amateur, by auxiliary mechanisms, and general simplifications, to make actual assays of gold, silver, copper, tin, and lead, after a few hours of personal instruction, or by the instructions contained in this book; the machine treating ten times as much as the com-

mon blow-pipe has ever reduced before; the tools are also present for all kinds of discrimination and analysis: as fusion of ten or twenty grains on unfluxed charcoal, or with an alkaline carbonate, etc.; roasting sublimation, test tubing, and ignition; drying, evaporating, boiling, distilling, filtering, etc.; so that such extended studies are hereby encouraged to a remarkable degree.

Naming one or two of such works may be an injustice to others; but the publications of *Harkort and Muspratt's Plattner's Qualitative and Quantitative, Berzelian Blow-pipe Analysis,* have legitimate claims for originality and completeness; whilst the valuable eclectic text-books of *Elderhorst's Blow-pipe Analysis for the Records of Mineral Reactions,* and *Dana's Manual of Mineralogy, for the Physical Properties, Composition, etc., of Minerals,* are well adapted for the general reference of the explorer, miner, miller, and metallurgist.

All of the necessary tools and fluxes, excepting such as are used in mining camps, and the acids and other liquids (which should be carried in a separate case), for the following tests and assays, will be supplied with the machine; and the few others that are required by these authors are described in their works.

Fig. 14.

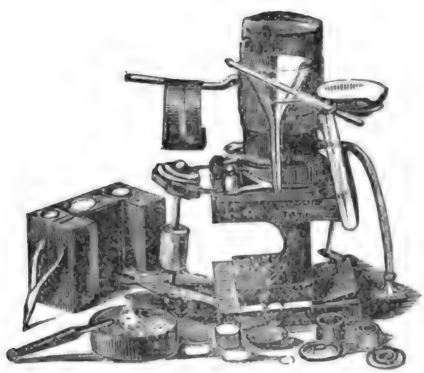


The accompanying illustration shows the Portable Prospector's Assaying Machine, when packed for traveling, in a five-inch or six-inch box.

In the following discriminations, a few examples will be selected to illustrate the necessary operations for exposing some of the peculiar reactions of the minerals, so as to procure sufficient manipulative skill for the application of the various tests recorded in the alphabetical list of mineral reactions contained in Chapter VI, Section III.

To erect for work, first unscrew the cap or mortar from the top of the machine; remove the flux box and column that are seen on either side; open the tool-boxes around the bed-plate; unclasp the spring-fingers; take off the sieve from this column, and spread all the appendages and tools around the apparatus. You will next see, by taking out the bell-cup, that the internal anti-return valve and its joint are air-tight. If these are not in good condition, take out this valve-box by simply drawing and shaking it from within, and gently forcing the rubber tube in from without, sufficiently far that you can have the valve-box, and that part of the tube without the body of the machine, for rectification; replace it in a similar manner, by drawing the rubber tube outwardly,

Fig. 15.



(Arranged for the general purposes of the Analyst and Assayer.)

and jostling, when the both joints will be simultaneously tightened. Next, place a rubber ring under, and another over, the flange of the inverted bell-cup, and replace it into the stuffing-box, with its long tube down in the opposite corner to the valve-box; pour water down this tube, into the square chamber of the machine, until it rises just to the bottom of the bell-cup; screw the cylindrical column down on the rubber rings, moderately tight, and stop the blast-pipes quite tight, by placing the two conical handles of the nozzles into them; gently blow in by the mouth-piece a full breath, which will raise the water into this column. If the water does not retain its height, there is an air leak somewhere. If it is from the internal square chamber to this column, by

way of the rubber joint, it will be evinced by continuous air bubbles arising therein. If the water descends in the column, without bubbling, there is an outward air leak from the square chamber, most probably by way of the valve or its joint, which will cease after they have been soaked supple by the water; or it may be from around the handles that are in the blast-holes, which will be no inconvenience when the machine is in blast, unless the loss is excessive.

If the rubber rings leak water outwardly, they have not been properly placed in position. After this blowing part is ready, and the nozzles do not blow water through, the wicks can be placed in the four-holed lever, of such a size that they shall just rub in the holes sufficiently tight for keeping their positions, but allowing perfect freedom for the capillary action of the oil, or the flame will not be supplied in sufficient strength and purity for the smelting to be performed successfully. This may be seen by the wick being dry, or in red combustion, instead of being merely the absorbing or carrying channel of the oil, for supporting the flame. The trimming the wick properly is the most difficult part of the operation; it should be so cut that it shall run in a parallel diagonal line with the descending blast; be free from stray fibers, and just so large that a clear, well oiled flame shall be produced, rather than a too voluminous, ragged-topped and scattered smoky flame.

The wick-chamber may now be filled with *olive oil*, when the machine will be ready for the *discrimination of minerals on charcoal*, from their general comportment, as decrepitation, change of appearance, or color of flames; smell of the more volatile oxides or acids from sulphur, arsenic, etc.; fusibility with or without fluxes; comparative dispositions towards reduction to their metallic states; whether magnetic or not, after fusion; change of color; loss of weight from volatilization, or combustion; colors of slags, either alone or with collateral wet tests, etc., etc.

Or for examination in forceps, for some of the preceding, but more particularly for the colors of the flames produced either with or without chemical tests; for comparative fusibility of the more infusible minerals; for the change of its

color, or friability; as well as for the characteristic lights and peculiar smells induced by heat.

Or for examination by a small platinum (or iron) wire, crooked into a terminal eye, in which, after certain fluxes are fused, the minerals are added in minute quantities, and again smelted; when many of the minerals are most easily detected by the color, appearance, and changes, produced by the oxidizing and reducing flames; many of which are wonderfully prompt, delicate, and reliable.

And, lastly, *by open and close-ended test tubes*, in which the pulverized minerals are subjected to the decomposing power of heat, sometimes aided by fluxes, either over a flame from an alcohol lamp, or before that of the blow-pipe across the wick; the more volatile giving off oxides or acids, gases or fumes, that are most readily recognized by sight, smell, etc., etc.

THE OXIDIZING AND REDUCING FLAMES.

To produce positive reactions, it will be necessary to thoroughly understand what governs the result.

In regard to these flames, much has been said and unsaid, both by European and American authors, which has muddled rather than elucidated this subject, by anomalous contradiction, arising, I think, from their endeavoring to account for their different powers by purely chemical creations before or within the flames themselves, rather than from the mere mechanical positions, that warm, or completely extract by actual combustion, the atmospheric oxygen that is driven before blast.

In the following exposition of the flames, those that are driven across the natural flame of the lamp, at a declination of about 10°, before the blast-pipe, are meant, excepting when the original flame of the lamp is purposely expressed.

From long practical observation, I am led to believe that the volatilization, or decomposition and oxidation, of a mineral is produced in an atmosphere that contains intensely heated oxygen, which, being thus induced, directed, and pressed, at fifteen pounds per inch, to actual contact with the substance for which it has thus acquired a suitable affinity for the hot mineral and metallic fluid, and no other substance being present, it necessarily completes its union therewith,

whether the hot air is produced and driven by blue or yellow flames; and, as proved by a furnace muffle, nothing more than sufficient heat is required to consummate this union; nor is it facilitated or retarded, when exposed, or in the muffle, by color or composition of the distant or outer heat-supplying flames, be they yellow or blue, carmine or green.

The oxidized minerals are also reduced or smelted into metals, when gaseous oxygen is excluded, or attached by some other element having a greater affinity, as hydrogen or carbon, whose combustion, by preventing the entrance of atmospheric oxygen from without, and uniting to that of the mineral, the mineral is reduced to metal.

In practice, the whole more cylindrical mass of the flame is better adapted for reductions, because of its amplitude and power; and the small, cone-shaped and clean blue flame is infinitely better for oxidation.

For the general purposes of qualitative and quantitative analysis, these flames have been recommended by Berzelius, Harkort, and Plattner; and the best and most concise description that I have seen of them is contained in the rudimentary treatise of Dr. Robert H. Lamborn on the *Metallurgy of Copper*. He says:

"When the point of the blow-pipe is held about one-third the breadth of the wick in the lamp flame (as in Figure 4), a flame is produced by blowing that is long, slender, and blue; is hottest at the outermost point (*a*), and is an oxidizing flame. This action, however, is strongest slightly beyond *a* (about *d*), in the stream of heated gas.

"If, now, the point of the blow-pipe be held as in Figure 5, somewhat higher than before, and not quite within the flame, a larger and more luminous cone of burning gases may be driven in the direction *b*, *c*; within the bright portion of the flame at *a*, the above mentioned chemical action on oxides takes place, which causes this to be called the reducing flame." (These cuts, being unnecessary, are not given.)

His description is all-sufficient for every purpose of the analyst and assayer, and is the most convenient manner for obtaining such flames.

For those who will use a common or the machine blow-pipe lamp, burning olive oil, for discrimination and assay, as

directed in this work, these flames may be further described and produced as follows:

The whole flame driven before the blast, touched by the nozzle at the first end, when completely enclosing the test sample with fire at the other end, is the reduction or smelting flame.

Oxidation is best realized one-quarter of an inch beyond a small, conical, blue flame's terminal point.

Produce these in any manner you may, the first will reduce, and the last will oxidize.

The reducing or smelting flame is obtained before the machine, at about where the wick-lever stops after outward traverse. The oxidizing flame is produced at or near its inward ascending limits, which can be transversely perfected, when necessary, by the elevating screw beneath the handle of the wick-lever.

DISCRIMINATION ON CHARCOAL.

Cut a piece of sound, well burnt pine charcoal, by first sawing it vertically as the tree grew, or lengthways with the branch, as planks of lumber are cut, to about three-fourths of an inch thick, and not less than two inches square; on one of its flat or largest sides cut with your knife a small recess of the size and shape of a split pea, near unto either edge, into which put a piece, no larger than a grain of wheat, of the mineral for examination; or, if a powder is to be tested, the same quantity may be moistened with water into a paste, and pressed with the point of a knife into a similar concavity, so that the blast shall not scatter it from the coal.

For mere examination, light the nearest lamp, and use the nearest blast-pipe only, by placing the handle of the third and fourth twin pipes into the large main supply pipe, and your small clearing needle into the second orifice.

After the lamp has burnt for a minute, trim off any stray fibers, collect the wick into snug shape, and in proper position before the nozzle, so that, when the blast is applied, by blowing a full breath into the machine occasionally, a voluminous yellow or conical blue flame can be produced at pleasure (by the appropriate motions of the wick-lever, and its transverse screw), for reduction and oxidation.

It will be imperatively essential for accuracy that the

charcoal be first tested by the flames, before any mineral is placed thereon, so as to be aware of the effects produced; as some coals acquire a coating or coloring from innate impurities, that too closely resemble some of the mineral oxides.

EXAMINATION OF THE VEIN STONES, AND MINERAL MATRICES, ON UNFLUXED CHARCOAL; AS QUARTZ, HEAVY SPAR, FLUOR SPAR; CALC SPAR, OR THE OTHER CARBONATES OF LIME, GYPSUM, MAGNESIA, AND ALUMINA; WHEN SEPARATED FROM THE METALS AND METALLIC MINERALS.

A fragment of matrix or gangue stone from a vein or mineralized pocket, being placed in this recess of the charcoal, it must be held, for about one minute, before the oxidizing flame, during which, if it is not pulverized, you will notice whether it decrepitates (or suddenly bursts with a crackling noise into fragments), as fluor spar (fluate of lime), and heavy spar (sulphate of baryta); if it changes color, as gypsum (sulphate of lime), which immediately becomes white, and crumbles into plaster-paris; or whitens, and becomes opaque, and luminous on the edges, as the calcareous spars; or phosphorescent blue, at a moderate heat, even after leaving the fire, as fluor spar; or partially or entirely fusible, as heavy spar, fluor spar, and gypsum, under long-continued intense heat; or infusible, as quartz, carbonate of magnesia, aluminous earths, and the carbonates of lime.

ADDITIONAL COLLATERAL TESTS, BY CARBONATE OF SODA, WATER, SULPHURIC ACID, AND NITRATE OF COBALT SOLUTION, ON THESE VEIN AND POCKET STONES.

First, add a drop or two of nitrate of cobalt to the fused stone or powder, and re-apply the flame for a few seconds; and observe, after it becomes cold, if any change of color has been produced. If brownish pink or flesh-colored, magnesia is present in some of its compounds; if pale blue, alumina, as a component of a clay. When magnesia and alumina are both present in a pulverized sample, they can be more easily and positively recognized through a magnifying glass. These reactions or changes, thus produced, are very characteristic, as nothing can conflict therewith in practice, unless borax and manganese, or borax and nickel, are also

present, which would form somewhat similar beads to that of nitrate of cobalt and magnesia; whilst, if borax were present, it would also form a blue with the cobalt from this solution.

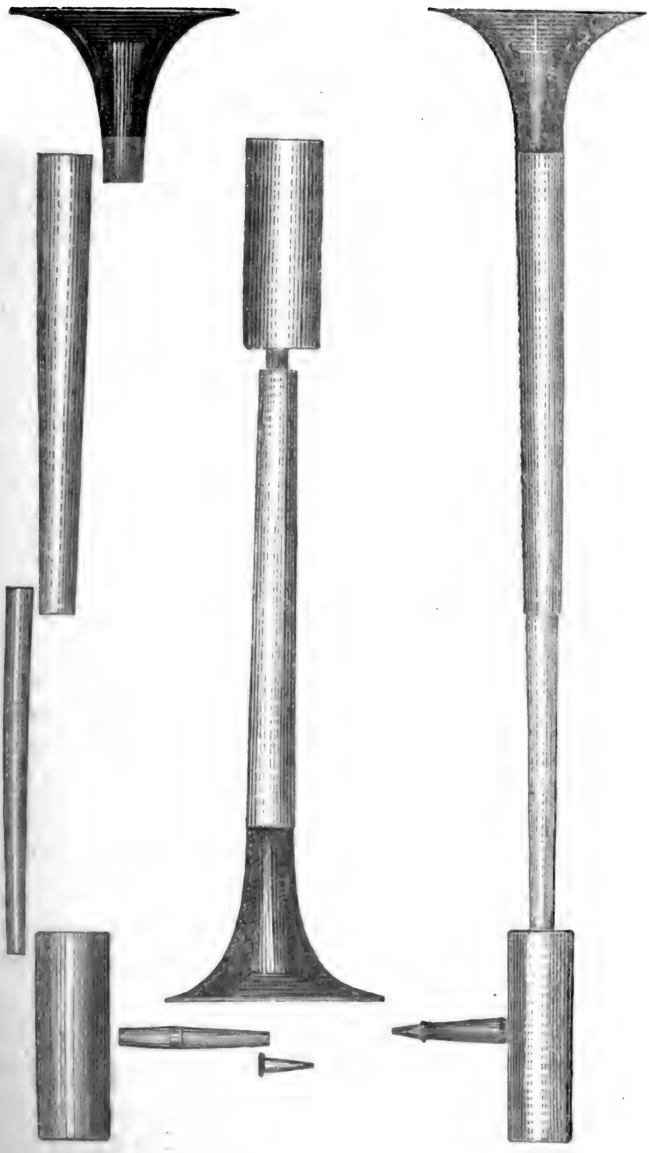
Quartz may be distinguished from heavy spar by not losing weight under fire, and by being fusible with carbonate of soda on charcoal, and by not giving the sulphur reaction by coloring silver brown or black, when moistened with water and placed thereon, after this fusion with carbonate of soda.

Heavy spar contains sulphur, and therefore loses weight, under the volatilizing power of fire; gives this sulphur reaction with carbonate of soda, and is still infusible therewith.

Fluor spar can be most easily recognized before a flame, or by throwing a stone into a fire, situated in a comparatively dark place, where each scattered fragment will exhibit a very peculiar phosphorescent light for some time after it has left the fire, which resembles nothing else, and, once seen, will never be forgotten. This stone is composed of fluoric acid and lime, and, when decomposed by warm sulphuric acid in a *glass* vessel, the released fluoric acid, having a strong affinity for silica, immediately attacks the glass, and, by destroying its polished surface, produces a frosted or etched appearance. This may be performed on a smaller scale on charcoal, by moistening the sample with sulphuric acid, and treating it beyond the point of a clean flame, so that the escaping acid may impinge on the glass.

The other lime stones may be generally known, after having been well burned, by their slacking in water, similar to the commercial article; the carbonates of lime, by their somewhat violent effervescence in all of the strong acids; and gypsum, the sulphate of lime, may be known, in addition to the test already given, by the sample being fused with carbonate of soda on charcoal, as above, which, by producing a sulphate of soda, that is soluble in water, colors the silver from brown to black, according to the quantity present, or time allowed for the reaction. This test becomes much more prompt and delicate, when the silver coin that supports the sulphate solution is warmed over a lamp.

CUT 16.

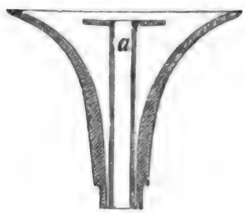


Cut 16 represents a telescopically arranged Berzelian blow-pipe, that may be carried in the vest pocket, which I have made after the manner shown by the triple illustrations, as fixed for use; separated; and packed for traveling; which explain themselves.

The ordinary form, though most convenient and exceedingly small for laboratory uses, is untowardly long for the prospector's pocket, and general itinerant purposes.

In the section of a portion of this blow-pipe, Cut 17, *will be seen, within the mouth-piece, another peculiarity—the small inserted flanged tube marked a; which most effectively prevents the water that would otherwise pass from the mouth into the blow-pipe, and over the charcoal, during long blowing for the various quantitative results.*

Cut 17.



Its action is most complete, as the water cannot turn the corner of the flange. It can be easily applied to any bell-mouthed blow-pipe, and as it is always better and less tiresome to receive the bell within the mouth, *to be pressed by the blast against the interior of the lips,* than to *press it mechanically against their exterior,* no inconvenience can arise from its presence.

EXAMINATION OF THE MORE USEFUL METALLIC MINERALS, BY SMELTING WITH FLUXES ON CHARCOAL, SOMETIMES ASSISTED BY WET TESTS.

Take, for an example, about one grain of the pulverized sample, prepared in the manner described in Section III, Chapter III, page 130, and, after mixing it in the mortar with its bulk of carbonate of soda, pulverize it with a little water into an impalpable thick paste, and place it in a cylindrical cavity about three-eighths of an inch in diameter and three-eighths of an inch deep, formed near one edge, on the flat

side of the coal. Blow a very gentle oxidizing, blue flame, thereon for one minute, and then the whole of the yellow reducing flame, which must completely cover the sample, for two minutes; and, lastly, the oxidizing flame, with the sample about three-eighths of an inch beyond the conical point of this blue flame, for about a minute longer, when you may cease blowing, and carefully examine the appearance of the charcoal, both when hot and when cold.

At some distance from the cavity that contained the sample may be seen, whilst it is still hot, the orange-yellow oxide of lead, which will become sulphur-yellow when it is cold. The oxide of zinc is also yellow when hot, but white when cold; and, when the oxide of lead is also present, the yellow becomes narrower when cold. Close to the assay will appear the heavier white oxide of tin, which, after it has been moistened by one drop of the nitrate of cobalt solution, and fused before the oxidizing flame for about a half-minute, it will show, when cold, a change to the characteristic color for tin of greenish blue; and, further from the assay, the green of zinc. You may also see, with a lens, the clear *pale blue* of alumina, and the flesh colour of magnesia in patches of the slag.

Now, by moistening the mass with hydro-chloric acid (muriatic), and re-flaming, the first flame produced thereby will be blue, and then, after a few seconds, the green flame from copper will appear.

Next, lift the whole slag from the charcoal, and apply it to the magnetic needle of your compass (which should have a removable glass for this purpose); it will be magnetic from reduced iron, or iron from the mortar (which might have been prevented by bruising in brass or between stones).

Lastly, the presence of sulphur may be recognized by laying the sulphate of soda, thus formed in water, on silver, as in the previous examples.

This is a complicated case, and, as regards the earths, the colors are too much mingled by fluxed fusion, and obscured by mineral oxides, for reliance thereon; but it serves as an important illustration of the value of the preliminary water separation, as described in Section III, Chapter III, and as an

example for the less intricate cases in the alphabetical list of mineral tests recorded in Chapter VI, Section III.

EXAMINATION IN FORCEPS.

The platinum-pointed forceps are most appropriate for this work, as they resist all single acids as well as the ordinary fire; but a small iron wire may be turned round to form natural spring-points for most occasional purposes, as they resist to some extent the heat from the blow-pipe, do not color the flame with the re-agents that are used, and if the test is saturated with the acid, when off from the wire, it will serve for some considerable time, in the absence of the superior article.

The forceps are used for holding small pieces of mineral between their spring-points, in the flame, without fluxes, but occasionally with an acid; and it is best adapted for observing the changes produced by heat alone, as decrepitation, luminosity, and color; the fusibility of the more infusible earths, the colors of the flames or changes generated by heat alone, or aided by some wet solvent; as well as the characteristic smells that are evolved, and magnetic properties.

To apply this test, just seize a small, sharp-edged piece of the mineral, about the size of a pin's head, between the self-closing spring-points of the forceps, and after it has been acted on by a clear, strong flame for a few seconds, to notice if it decrepitates, changes color, or becomes lustrous, or fuses entirely, but partially on the sharp edges, or not at all; if the flame shows any peculiar color, either before or after the mineral has been moistened by a characteristic solvent, as that of hydro-chloric acid for copper, which, after first giving a blue, from chlorine, concludes with the green from copper; if it is magnetic either before or after long-continued blowing; and, lastly, if it slacks like lime in water.

DISCRIMINATION BY FLUXES IN THE PLATINUM WIRE.

This method for qualitative analysis, so portable, and convenient for use, and wonderfully prompt in action, frequently obtains the most incontrovertible and astounding results; requiring but a mere speck of the mineral, it acquires as much information in a minute, as regards its more palpable

reactions, as other means in several hours; and so easily, that it is in such cases invaluable for the mineralogist, metallurgist, and general chemist, in dealing with some minerals, metals, and chemical precipitates; the more so because many of them are the most difficult by other re-agencies.

The miner and metallurgist will realize those of the following examples in his practical avocation:

For illustration, a sample that becomes magnetic after complete fusion on charcoal, from the presence of iron, or nickel, may be pulverized, then well washed with warm water, and examined thus: Take a piece of small platinum wire (of the size of the smallest bird-cage wire), from one to three inches long, which place in a metallic or wood handle, as you would a brad-awl; next turn the outer end into a small hook, like a shepherd's crook, or an eye, of about the shape and size of the note called semi-breve in musical notation; hold this terminal eye into the clean oxidizing flame until it becomes red hot, then dip it into some pure borax glass (borax previously fused in a crucible), and warm it in the flame until this loop is filled to a colorless bead, which cool, and moisten it with water, if the sample to be tested is dry, so that a small portion may adhere thereto, or dip it therein if it is wet, as the above, or as a chemical precipitate would generally be. Now, if the magnetic mineral or metal is iron, the bead will be changed by the oxidizing flame to red whilst hot, and yellow when cold, and to bottle-green in the reducing flame, and when a particle of metallic tin is added thereto, it intensifies this color to copperas green.

If the magnetic mineral is cobalt, it will produce a bright blue bead, hot and cold, in both flames, with borax.

If the magnetic mineral is nickel, it will be violet when hot and reddish brown when cold, in the oxidizing flame, and, after long blowing in the reduction flame, colorless. For more positive proof of the presence of nickel, the absence of manganese must be demonstrated, which gives a somewhat similar bead, and, being frequently associated with iron that attracts the magnet, would thus too closely resemble nickel. The presence of manganese may be most readily ascertained by thoroughly cleaning the platinum wire from borax, and testing in a similar manner with a clean bead of

carbonate of soda; if manganese is present, the glass will fuse to a very characteristic green, which becomes bluish green when quite cold; whilst the nickel would be reduced in this flux to the metallic state; and if smelted with carbonate of soda on charcoal, then pulverized, and water-washed as described in the latter part of this chapter, the metallic nickel may be extracted from the liquid, or its dried residue, with the magnet, and reëxamined by borax. The manganese and cobalt cannot be thus reduced, and the iron is known by the dissimilar bead.

The characteristic colors of the fluxed mineral beads, when some of the minerals are in excess, can be much more easily performed and distinctly recognized when pulverized than by the flattening of the hot slag between forceps, as described by the authors.

The above example should serve to show the importance of keeping the fluxes separate, and obtaining them chemically pure, as otherwise much confusion will result.

Another application of this method of testing will suffice both for colors of the beads and flames:

Prepare, in a similar manner, with microcosmic salt (the double phosphate of soda and ammonia), a clear bead, which fuse with oxide of copper to saturation, or with mineral copper oxidized with this re-agent of microcosmic salt, before the point of the small conical blue flame, until it shows the strong characteristic colors of green when hot, and blue when cold; next add thereto any substance to be tested for chlorine, as hydro-chloric acid, chlorides of sodium or ammonia, chlorides of silver, zinc, or copper, chlorides of calcium, barium, etc., etc. If chlorine is present in any form, an intensely blue flame will be produced, beyond the point of the oxidizing flame and sample, in the ignited gases that are driven before blast; and, if hydro-chloric acid is being tested, as it is also a solvent of copper, after the chlorine flame passes away, the characteristic green flame of copper will appear; and, when chloride of sodium is being tested, that of the strong yellow flame produced by soda will predominate, the blue from the chlorine showing on the borders during the first few seconds only, whilst the soda will be visible for some minutes.

This test for copper may, however, be more easily applied in the forceps, by moistening the unfluxed solid with hydrochloric acid, and placing it in the heated current produced by the oxidizing flame.

DISCRIMINATION IN CLOSE GLASS TUBES, OVER THE ALCOHOL LAMP.

To form a tube stand with the machine, place the cylindrical roasting furnace on the pressure column, and screw on the short double-jointed lever thereto, as seen in Figure 15, page 138; attach to its outer end the three-holed tube-holder, and insert a close-ended test tube in one of these holes, so that it shall have an angle of about 25° from the horizontal. If you have no alcohol lamp, take a common conical ink-bottle, and drill a hole in its cork sufficiently large to receive *loosely* an empty cartridge from a small pocket-pistol, and then to stamp or drill, with the point of a knife or scissors, a one-fourth inch hole in it to receive a cotton wick.

To operate on a sample supposed to contain mercury (probably sulphuret), which, being very volatile, requires this close treatment; you may mix about one grain of the ore with its weight of dry carbonate of soda, which place in this tube of about five-eighths of an inch in diameter and closed at the one end, and gradually apply the heat of the lamp underneath for about ten minutes. If mercurial ore is present, it will be decomposed, and the volatilized metal will settle in the upper and colder part of the tube, and can be collected by rubbing with a glass rod, or knife, and easily recognized in white metallic globules by a lens. A still more delicate test is that of inserting a piece of gold leaf, wrapped around a small iron wire, into the tube to about a half-inch above the heated sample, being suspended to position by a suitable crook at its upper end; if the smallest quantity is present, it will whiten the gold by amalgamation.

DISCRIMINATION IN GLASS TUBES OPEN AT BOTH ENDS.

These tubes should be about one-fourth of an inch internal diameter, and may be passed loosely into one of the holes of this three-holed lever, in such a manner that it shall rest securely therein, when dipping at an angle of from 20° to 30° from the horizontal; the mineral to be examined must be

pulverized, and should lie within about three-fourths of an inch from the lower end of the tube; the natural flame from the alcohol lamp—or sometimes, when greater heat is desirable, the blow-pipe flame—should be applied at about one-third the length of the pulverized mineral down from its highest end; some minerals are thus decomposed, and their more volatile elements are carried upwards by the rarified gases, and either re-settle in the colder parts of the tube, with characteristic colors at their respective distances, or, passing through the upper end of the tube, they are detected by peculiar smells, acid properties, etc., etc., as well as from all these peculiarities, in connection with the tests by other methods; antimony from its flowery perfume, and arsenic by its disagreeable garlic stink, the both by their white volatile oxides, in the tube, and in the smoke that passes through; sulphur by its yellow and yellowish-white oxide on the interior of the tube, and by the well known smell of sulphurous acid. (See Chapter VI, for Mineral Reactions.)

These examples will be sufficient for exposing the various methods of manipulation, and they may be further varied and extended to suit the records of mineral reactions, in the numerous tables that have been published.

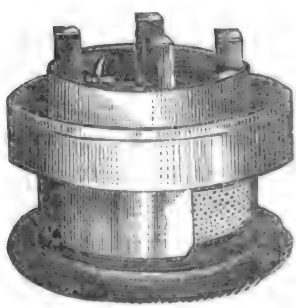
EXAMINATION BY SMELTING AND WATER-WASHING.

For qualitative-quantitative information, to ascertain if any, or what, smeltable minerals may be present in a stone, it is often very efficacious to fuse a quantity of say one grain with the ordinary blow-pipe, or ten grains before the machine, of the pulverized sample that has been passed through its sieve, and further rendered impalpable in the mortar, as follows: With the mineral thus prepared and weighed mix its volume of carbonate of soda, and half its volume of borax glass, and after it has been placed in a paper cartridge, and fused by the reduction flame for some ten minutes, the fusible metals, if any are present, will be reduced, either as an alloy, or separated according to their dispositions, etc. Next pulverize to a fine powder, without sifting, and wash with water, as described in the chapter on water treatment, which will pass away the soluble and lighter debris; pulverize, by rubbing the wet remainder under the pestle; re-wash, to pass

oft all but the flattened metallic disks, which may be fully examined with the naked eye for practical purposes; but, when vision is assisted by a magnifying glass, the most minute quantities can be thus detected, if the manipulations have been carefully conducted, and the metals, when not alloyed, recognized by their colors, etc.

I have just received the particulars and drawings of the following machine from my brother, John Phillips, who (having been for many years the local Government's Mineral Surveyor of the Ballarat Gold Fields, and since Surveyor and Registrar of St. Arnaud Districts, of Australia), seeing the great necessity for more convenient, economical, and yet efficient, means for preliminary examinations of extensive bodies of auriferous quartz in that country, contrived the compact combination of mortar and pan for simultaneous pulverization and amalgamation, as shown by Cut 18, which he calls the "PORTABLE QUARTZ REEF-TESTER."

Cut 18.



He has also contrived an exceedingly ingenious and skillfully calculated (though less practically useful) gold-valuing lever, for ascertaining at sight the quantity of gold contained within any nuggetized stone of quartz, of course when other substances are absent, which is more frequently the case in the gold fields of Australia than elsewhere.

It records the answers to twelve separate desiderata, and this, too, without the use of any weights, being simply ascertained by equipoise of the test sample with a lesser substance, as governed by the relative specific gravities of the more or less auriferized quartz.

CHAPTER V.

DISCRIMINATION OF THE USEFUL AND PROFITABLE MINERALS BY A NEW METHOD, FOR PRACTICAL MEN.

These modes for examination are intended for practical men, who have no other tools than can be found in and around all prospectors' and miners' camps.

EXAMINATION OF THE VEIN–STONE MATRICES.

In the examination of a stone that has been broken from a mineralized vein or pocket (which is in itself a safeguard for the absence of many other stones and earths, and confines the number to but a few for examination), first observe its color, hardness, crystallization, and weight, or specific gravity, by handling, or actual weighing, etc.

If it is white, and more or less transparent; rosy or rusty white; scratches glass, or is wholly or partially composed of six-sided pyramidal crystals, that terminate in an abruptly mitered point from the same number of sides, either at the one or both ends, and does not decrepitate (burst with a crackling noise,) or lose weight after being roasted for a half-hour at red heat; changes in no way, and still bruises with difficulty to a fine powder: it is quartz.

If the test stone is water-white, yellowish, sky-blue, greenish-blue, rosy red, amethystine, purple, deep purple approaching to black, very brittle, does not scratch glass, and is not scratched by the nail, crystalized *in cubical forms*, and on being heated in the fire, in a comparatively dark place, it *suddenly bursts with a crackling noise*, and scatters into numerous pieces, which exhibit *peculiar phosphorescent lights*, that vary in color as much as the mineral itself, and *continue visible for some time after it has escaped from the fire:* it is fluor spar.

If the stone is white, rusty white, yellow, greenish or grayish-blue, too soft to scratch glass, and *does not decrepitate* when placed in a hot fire, but becomes *lustrous when very hot*, at the *latter stage* of one hour's roasting, and white when it is cold, having lost from a third to nearly half of its weight, becomes *caustic*, and *slacks and crumbles to powder in water:* it is one of the carbonates of lime, as compact marble, which resembles loaf sugar; or chalk, which is friable, and readily marks whatever it touches; or rock limestone; or calc spar, which is fine-grained, wax-like, soft to the touch, cuts freely, and is easily scratched by the nail.

These and other carbonates effervesce in all of the strong acids, which is good collateral evidence; but crystallization availeth nothing for your purpose in this example, as more than eight hundred modifications from the obtuse rhomboid have been observed.

If the stone is dirty white, yellow, red, brown, or gray; of a horny or pearl-like appearance; or bruises to a flour-white, or is easily scratched by the nail to this flour-like appearance; or cuts into thin, flexible flakes, and immediately whitens and crumbles in the fire, as if suffering pain, and speedily becomes caustic, with loss of about two-thirds of its weight, and slacks in water: it is gypsum (or hydrated sulphate of lime). As an additional proof, the sulphur may be detected by fusing some of the pulverized stone with carbonate of soda, or saleratus, which contains it, in an iron spoon, over the fire, and placing a piece of the slag on a silver coin, moistened with water, when, if sulphur is present in any form, the silver will be tarnished to a brown or brown-black, from the soluble sulphate of soda thus formed. This may be facilitated and intensified by placing the coin on a previously warmed stone, baking-dish, or other hot substance.

If the stone is white (or sometimes dirty yellow, bluish, or from red to brown on the faces, and bruises whiter); is of a sparry and glassy appearance, but does not scratch glass; decrepitates in the fire without luminosity or phosphorescence; lessens its weight, but does not slack in water; and gives the sulphur reaction on silver, as described in the preceding test for the sulphur of gypsum: it is sulphate of baryta, or heavy spar. The metallic mineral carbonate of

iron is sometimes white, but is unusual, and may be discovered by being roasted in a hot fire, after which it becomes magnetic, bruises red, and washes away in water.

This may be varied to suit certain cases, as occasion may dictate; as it will be seen that the sage-bush fire has no effect on quartz, which scratches glass; that, coupled with crystallization, this fire test is an all-sufficient detective for fluor spar, by exposing its properties of bursting into luminous phosphorescent particles; as also for the carbonates of lime, which are made to slack in water; and for gypsum, by causing it to crumble immediately into "Plaster of Paris" powder; whilst the heavy spar is distinguished from quartz, the carbonates of lime, and from gypsum, by decrepitation; and from fluor spar, by lacking its very characteristic phosphorescent light.

And the fusion with carbonate of soda in the iron spoon will prove (if it is white lead ore, by smelting it to metallic lead), the presence or absence of the sulphates of lime or baryta, when they can be distinguished by either whitening or decrepitating under the action of the fire.

If you have acids, they would prove the carbonates by effervescence, and quartz and gypsum by their insolubility.

SEPARATE DISCRIMINATION OF ANTIMONY, ARSENIC, AND SULPHUR, WHEN IN COMBINATION.

Cast a stone of the mineral into a fire; if antimony is present in practical quantity, it will fuse into a waxy slag almost immediately, which, burning bluish green, vaporizes off in copious white fumes, or a slight flowery odor; and if a rod of iron be placed therein, it will obtain a white coat from its condensed oxide.

If arsenic is present, a portion of it will volatilize at a slight advance of temperature, and the remainder at a still higher degree of heat, its white oxide settling on the cold iron as that of antimony; but it does not fuse to a slag, and emits an offensive garlic stink that can be easily recognized. The water-washed ore of antimony has a decidedly different appearance from those ores which contain arsenic.

Sulphur is known by its oxide being less voluminous and more yellow, but more decidedly by its stubborn, slow

departure, and protracted, peculiar, sulphurous smell; an extremely delicate test is that already described for the gypsum and baryta sulphates, *more particularly on the warmed coin.*

SEPARATE EXAMINATION FOR THE PRESENCE, QUALITY, AND PERCENTAGE, OF THE COMBUSTIBLE ELEMENTS OF COALS.

A mineral that is brown or black, and resembles coal, may be placed in an iron spoon, crucible, or other suitable vessel, within a clear fire; if it ignites into flame, and, on being removed from the fire, it continues to burn for some time, it is coal, and its quality may be judged of from the intensity and duration of the combustion, and comparative weight of the unconsumed residue of stone, clinker, or ashes; if this remainder can be blown out of the spoon with a light, natural, outward breath from the lungs, it may be safely pronounced a good commercial article, at least for the kitchen or parlor, if not for the steam-engine.

If you have a balance and a set of decimated weights, or the machine with its calculating balance, by first weighing one hundred grains of coal, burning it thoroughly and carefully in the spoon, and weighing its incombustible residue, you will obtain by this percentage its comparative value as a fuel; or, having an assaying machine's calculating lever, you may ignite in a crucible, placed in the roasting furnace, either one or ten balancings, with the weight marked B in the pan, and read the percentage of the residue under where it lies, when balanced with either of the weights marked X 5, X 4, or X 3, by taking off one or two figures from the right-hand side of the columns, as the one or ten weighings has been used for the assay, as fully described in the gold and silver bullion and base metal assays.

GENERAL EXAMINATION FOR ALL OF THE USEFUL AND PROFITABLE METALLIC MINERALS, TO ASCERTAIN THEIR PRESENCE, AND APPROXIMATE PERCENTAGES OF METALS.

To illustrate this system, we will take from a dried sample of pulverized mineral, prepared in a stone or brass mortar, as described in Chapter III, Section III, which is supposed to contain any one or the whole of the minerals and metals of

antimony, cobalt, copper, gold, iron, lead, manganese, mercury, nickel, platinum, silver, tin, and zinc; take therefrom about, or, if you have a correct weighing apparatus with decimated weights, exactly one hundred grains, which, after any magnetic iron ore that it may contain has been extracted by a magnet, compass needle, or a magnetized knife-blade, and placed in a heap on a clean plate for future reference, must be very carefully concentrated with water in two or three vessels, as fully described in Chapter III, Section III; and then, after the dried metallic residue of gold, platinum, or copper, has been placed in separate heaps on the plate that contains the magnetic iron, the remaining concentrated minerals must be collected into one of the basins, the water poured off, and the residual dried at about 212°, by simply placing this basin, as a lid, over a tea-kettle, sauce-pan, or coffee-pot, that contains boiling water, until the mineral is completely dried. Next sweep it with a rabbit's foot, rat's tail, a soft feather, or camel's-hair brush, from this vessel on to a perfectly dry and clean plate; scatter the particles, so as to examine their physical characters, and transfer them with a forceps into as many separate heaps, to ascertain their percentages, by weighing each mineral, and calculating its ratio of metal, if you wish, as described in Chapter III, Section III, for the water assay.

The minerals being separated from magnetic iron ore by the magnet, concentrated, dried, and each kind of metal and mineral placed in separate heaps on a clean plate, may be further recognized by the eye alone, or better with a powerful lens, as follows:

One portion, sulphuret of antimony, is grayish white, having considerable metallic, steel-like lustre, and shows irregular, flaky, divergent crystallizations, which can be better seen, however, before the stone is bruised.

Another contains lead, as galena, which is of cubical crystallization, more granular, straight-faced, and lead-colored, and less disposed to become impalpable under the pestle.

These are often mixed together, both mechanically and chemically—the former separating by water—and may be further examined and approximately separated by fire, thus:

Roast a small quantity, say ten grains, or, if by calculating

balance, by B weight, in a clean iron spoon, over a clear fire, or lamp, stirring the whole time with a small rod of wood or iron, and not exceeding black heat during the first ten minutes of the operation.

If sulphuret of antimony is present, white fumes will arise during this period, even at this heat, which will not smell of garlic, although it will coat the rim of the spoon or a piece of cold metal with its white oxide, when held in the fumes.

Next pulverize a small piece of charcoal, and, after adding a half-spoonful to the mineral, roast and stir for another ten minutes at a heat not exceeding a low red; remove it from the fire, and, after it is quite cold, add its weight of sugar, with four times this quantity of carbonate of soda, mix intimately, and smelt this mixture at the greatest heat obtainable in a common fire, the sample being covered by a few pieces of charcoal, for about twelve minutes.

If lead is present, it will be reduced to this well known metal; its purity can be ascertained by its flattening to a thin disk without fracturing the far-extended edges, and by its toughness when frequently bent across its middle.

If still alloyed with antimony, it will break under such treatment, and it must be again subjected to the moderate heat of the fire for short periods of about two minutes, until it stands this test, when it can be weighed for metallic lead; and, by deducting this weight from the original weight of ore, the quantity of sulphuret of antimony remains, which, being multiplied by 73, and divided by 100, will give the quantity of metallic antimony contained in the ore. Antimony sulphuret can be fused in the natural flame of a candle or lamp to a black slag, whilst galena is thus infusible.

If one only of these minerals is present, it need not be smelted, but can be weighed as a mineral, and calculated for metallic antimony as above, or for lead from its sulphuret, by multiplying it by 86.55, and diving it by 100.

It seldom occurs that the (white to yellow and brown) carbonate of lead (specific gravity, 6.47) accompanies the sulphurets of these minerals; but, when it does, it may be distinctly seen on the top of the (somewhat similar specific gravities) lead and antimony, which may be known by its color; and this must be entirely passed away before the lead-

colored residues of sulphuret of lead and antimony ores are separated by fire, as above, as nothing but gray sulphurets should be present.

The fourth pile is a blue, and, if in quantity, will most probably be the blue carbonate of copper. It may, however, be some of the other very rare minerals found in small quantities, that also exhibit this color, and must be tested for copper, as will be explained anon.

The fifth pile is green, and is most likely to be (particularly when it is generally disseminated through a ledge above the water-line) either the green carbonate or silicate of copper; the former may be distinguished from the latter by its friability, wax-like green, smoothness under the pestle, and by effervescing furiously and completely dissolving in nitric acid; the latter has a less waxy, paler green, and more flinty surface, is peculiarly harsh under the pestle, partially dissolves in this acid, leaving a residue of quartz.

As some other rare minerals are green, for absolute certainty these must be also more especially tested for copper.

The sixth pile is composed of one or more of the ores that vary from a metallic-lustred steel-gray to a dull and somewhat earthy dark gray to black, and may be a gray sulphuret of copper; an argentiferous copper; an argentiferous, antimonial copper; a ferruginous, antimonial, argentiferous copper; an antimonial sulphuret of silver; the arsenical sulphuret of silver; the gray sulphuret of silver; the black sulphuret of silver; or the black oxide of copper.

The seventh pile is from red to reddish brown; as the arsenical cobalt (cobalt ochre); arsenical nickel (copper nickel); the red oxide of copper (the oxide of iron will have passed away in mechanical suspension, as thick red water); sulphuret of mercury (cinnabar) which bruises to carmine red; and the light and dark red silver ores (ruby silver); and the sulphuret of zinc, which bruises and scratches red.

The eighth pile, which was taken from, or near to, the heavy head of the washings, will vary in color and appearance from the lightest to the darkest resin; as some of the iron ores; tin oxide (its only profitable ore), which passes through all the shades of this well known substance; tungstate of iron (or wolfram), its most persistent but worthless com-

panion, which closely resembles the dark specimens of tin ore; its specific gravity is too similar for separation by water, nor can it be expelled by previous roasting and oxidation; so that the oxide of iron may pass away as an impalpable powder mechanically suspended in the water, in the manner of the other ores of iron; but must be separated, after all the other minerals have been expelled, by acid treatment, as the last operation.

Apart from crystallization and specific gravity, garnet closely resembles tin stone, in many ways, as do some of the irons, manganese, and one variety of hornblende; but, excepting this single and very rare instance, tin can be recognized and isolated from the others, by roasting and water treatments, in a few minutes. In the pulverized condition, the garnet (which it most resembles) had passed entirely away with the hornblende in the water; the manganese occupied a lower position; and the other iron ores may be oxidized by roasting, re-pulverized, and passed away, by a repetition of the water process, when the redness of the water from the oxidized mineral will indicate the presence of iron oxide.

The ninth pile will be those earthy metallic minerals, without any resinous or metallic lustre, which vary from white, through all the shades of greenish yellow, to rusty brown; such as the oxide of lead, carbonate of lead, carbonate of iron, carbonate and silicate of zinc.

The first and second may be reduced with carbonate of soda, in the iron spoon, or on a piece of charcoal placed in the fire; the third changes color in a hot fire, and after some time becomes magnetic; the fourth, being a carbonate, effervesces, and is completely dissolved in muriatic acid; the fifth does not effervesce, but is partially dissolved, leaving a white quartz residue; and both of the last exhibit white fumes, when placed in a hot fire, that settle on iron or charcoal, which are yellow when hot, and white when cold.

The tenth, eleventh and twelfth piles may receive any *metals* that are present, as gold, platinum, copper, etc.; which, if the rock was pulverized in a stone mortar, may be known by their colors, as iron would not be present.

The thirteenth may receive such as vary in color from a

strong metallic-lustred white to a similarly bright yellow, which will contain, when in quantity, the arseniuret or sulphuret of iron, which, on being warmed to redness, will evolve the garlic smell of arsenic, or that of sulphur, and the residue will become magnetic after sufficient roasting.

The chloride of silver, when in minute division and small quantity, will mostly pass away; but, should it remain, it can be tested by rubbing a bright copper cartridge thereon; if chloride or chloro-bromide of silver, it will whiten the copper with a silver coating, which can be applied, also, to the unpulverized chloride faces of the stone. Graphite will also whiten copper or gold; but this ore is so different in color, having a bright, steel-like appearance, that it can scarcely occasion error.

In all cases, the lighter gangue minerals will have passed away in the water, and it will seldom occur that more than two or three of the metallic minerals will be present together, and they so different to each other, or you will be indifferent to some of them, that they need not interfere with the more straight-forward examinations, for such as will practically concern you.

There is no very safe common-place test for silver, when it is in small or even paying quantities, as will be very plainly seen from the fact that one-thousandth part, or two pounds, scattered throughout a ton, will equal $37.70 in value.

It occurs, too, in so many mineralized forms, that the best judges, without an actual assay, are often puzzled to even approximate its value. If you have some chemically pure nitric acid, you can test silver, when in paying quantities, as follows:

Take about one hundred grains of the pulverized ore, which mix with its volume of powdered charcoal, and roast during continual stirring with an iron or brass wire, for fifteen minutes, at a low red heat, until the charcoal is all burnt, so as to decompose any silver chloride that may be present (which is insoluble in all acids); remove the roasted ore to a tea-cup, and pour about twice its volume of chemically pure nitric acid thereon, and warm over a coffee-pot of boiling water, for some twenty-five or thirty minutes. Remove it from this position, and after it is quite cold, well settled, and

clear, you can test this solution for silver by pouring a few drops of salt water therein, which renders it milky, or precipitates a white chloride; as, also, by dipping a small strip of copper, cut from a rifle cartridge, in the original solution; if silver is present, this copper will be silver-coated therewith. This roasting is imperative in all instances, as, even when the silver ore is in a soluble form, salt, or some soluble chloride, may be present in the vein, which, by immediately precipitating the silver from the solution to an insoluble chloride, unless the sample was rich, would falsify the result from this or any other *acid* test.

The double treatment of silver ores by ammonia and nitric acid is too chemical and delicate for your purposes.

Copper can be very conveniently precipitated, known by its color, from a similarly treated sample, on iron, steel, or zinc; a clean, bright knife-blade being a ready and extremely delicate test, which must, of course, be applied before the copper test is inserted for silver, as it is partially dissolved in the solution, and would show a false copper coat.

This method of water concentration is not directly valuable for silver ores; but it is *indirectly* useful, as it exposes the presence of such as are most likely to contain it, and the kinds of the ores that more particularly require an especial assay for silver, by crucible, scorifier, or machine.

The silver ores named in the sixth and seventh lists, when they are dark, or cut freely, as well as the chloride, lead, and zinc ores, are always worthy of an actual assay for silver. The facts that all of the ores of silver worked by miners are comparatively soft, varying from about 1 to 3 in the scale (quartz being 7, and common salt 2), should be remembered, as well as their *not* being of a very pale metallic lustre, as it will guide you to such which should have a more especial test or assay, and away from the minerals having a pale metallic lustre, which are not silver ores.

This water treatment is thoroughly reliable for the assay of gold, platinum, metallic copper, and tin, when worked as described; as well as for all the others, as the ores of lead, antimony, copper, manganese, zinc, etc., from established mines of such, when free from confused mixtures.

For the actual assay of either of these by water, a quantity,

varying from 10 to 1000 grains, may be taken, and the residual of mineral calculated from the rule laid down in Chapter III, Section III, on Water Treatment, and in the respective chapters concerning the assays of each metal and mineral.

A most important part of this system of examination is that of comparison for specific gravity, which may be just now sufficiently illustrated by two examples; the first being that of yellow mica, which, when much flattened, resembles gold leaf. If in doubt, you may be rendered more positive by throwing some fine flattened gold in the test, when, on the repetition of the action of water, it will be seen that the gold (of specific gravity that varies from 14 to 20, as it is more or less alloyed), will take a concentrated upper position; whilst the mica (of a specific gravity of but 2.9) will scatter and oscillate more freely in the current of water, and settle at the lower end, or pass away over the margin as you may desire.

The second may be platinum (of from 16 to 19 specific gravity), or a sample of graphite (of 2.1 specific gravity), and the only lustrous white substance present; now this, as well as one kind of mica (the two-axed mica), are, like platinum and gold, insoluble in any one acid; and graphite further resembles platinum by being also infusible in the ordinary blow-pipe flames; so that the acid test is inapplicable, and this is at hand to separate and distinguish by greater stability or floatability in water, in the manner described.

These are extreme cases to show the means by which the ordinary pulverized samples of iron pyrites or yellow copper may be sprinkled in the former; or galena, or sulphuret of antimony, in the latter; or any other minerals that you would test by specific gravities, by using the one as a comparison for the other, as tin oxide (of about 7) against manganese oxide (of about 4), etc., etc., being of similar colors, or some other close resemblance that requires additional collateral evidence.

Two other important advantages arising from this preliminary water treatment, and which should be now mentioned, are: First, that the gangues having been all separated and passed away, the confusions that would otherwise arise from their occasional interference with the metallic minerals' reactions, or by their excessive annulling quantity, can no longer

prevent the most direct tests being made. Secondly, that of parting the metallic minerals in heaps affords another means of examining, from the exposition of certain peculiar physical characteristics, which in some instances greatly assist the amateur in seeing which of the two or more metallic minerals are present, that give reactions that are too similar, by other means; as those of lead and bismuth, which deposit their yellow oxides on charcoal, both hot and cold, but whose metals and minerals are so distinctly different in appearance, that you may see at a glance which is present by re-observing the washed sample from whence it was taken; or, if a small quantity of lead ore is with that of zinc, it will show itself, and prevent your being deceived, by the over-covering of yellow oxide of lead on what would otherwise be changed, on cooling from yellow to the white of zinc, when alone; as also when tin and zinc are in company; or antimony and tin, etc., etc., which are all so decidedly different in their mineral states, although similar in others, that they afford much more information on the subject than you can obtain from sources that are either beyond your knowledge or the facilities of your camp.

Copper may be detected, in all of its combinations, in a very simple manner, by precipitating it, on iron or zinc, from its acid solutions, as described in the wet test for silver; or it may be moistened into a paste with hydro-chloric acid, and thrown into a fire, when, if copper is present, even in very small quantity, after the first intense blue flame, caused from the chlorine, has disappeared, the characteristic and beautiful green flame of copper will follow. If you have no acid, take either of the pulverized samples supposed to contain copper, and intimately mix it with its bulk of dry salt, and after kneading it into a ball with candle-grease, lard, mutton, beef, or any other fat, moistened with a few drops of water which has been made as salt as possible, it may be cast into a bright fire, when the characteristic colors, first blue and then green, of copper, will also appear. Some of the copper ores will show the green flame by fire alone. This is best accomplished in the night, as the colors are much more distinct.

If copper is present in the dark gray ores, it does not follow that silver is absent, as some of such carry copper and other

metals in their constitutions, and they should be tested—or, more properly, assayed—for silver.

It will be seen that the seventh pile should also be tested for copper, which can be done very easily, as both the black and red oxides give these flames most readily. It may also contain cobalt, nickel, iron, mercury, the red silver ores, and sulphuret of zinc, which bruises to dark red.

Cobalt may be known by being intimately mixed and fused with borax in an iron spoon, which produces an intense blue glass, that can be best examined by a lens, after pulverization.

Nickel produces, with borax, in the same manner, a reddish brown glass; but, as manganese gives an amethyst and purple glass, it may be mistaken; so that this sample should be similarly treated with carbonate of soda in a clean iron spoon, when, if manganese gave the amethyst or purple, it would also show its very characteristic bluish green glass with carbonate of soda.

The colored flux tests must be performed in a hot, clear, and open fire, so that complete fusion may be produced in a free current of air.

Iron has been already explained; but another means may be applied, in the absence of a magnet or chemicals: Roast and stir for an hour, at a red heat, with powdered charcoal, or two hours without it, in an open vessel, and increase the heat towards the end; and, if convenient, allow it to gradually cool down with the fire itself, over night. Place this well roasted ore in an open saucer, sprinkle it with salt, and just cover it with water; if iron is present, it will rapidly oxidize, and, in a day or two, rusty water will indicate its presence.

Copper ores may be tested without the salt, in a similar manner, by strong vinegar, when, if the ore contains copper, it will become, in a day or two, from blue to green.

Mercury can be examined by placing an equal quantity of carbonate of soda and the pulverized ore in a thin oil flask, and applying the flame of a lamp underneath, when, if mercury is present, it will be reduced by the carbonate of soda, and sublimed to the upper part of the flask, where it will again cool, and settle in minute metallic globules, that can

be scraped together by a bent iron wire or other smooth rod, for better examination.

It may be also thus performed in an old gun or pistol-barrel, or even a clay smoking-pipe, by stopping its mouth, and firing up and driving out the fumes that may be caught without the pipes, on a cold metallic substance; or, by inserting a gold coin in the metallic fumes when it is treated with carbonate of soda, it will be amalgamated thereby, and may be known by its mercurial brightness after it has been rubbed, as the oxides from the other volatile minerals would be thus rubbed off.

The ruby silver should be tested in a recess, on a piece of charcoal, with its bulk of borax, in a hot fire, for some ten minutes, and then removed and examined for metal. None of the others would produce metal in this manner.

Zinc may be also tested on a piece of coal, which would, if placed in an open fire, oxidize this mineral, and, on removing the charcoal from the fire, it will be seen that the *hot* oxide of zinc is yellow, and the *cold* oxide is white, when lead is absent, which will be very certainly known by this method.

Tin, after it has been roasted, can be examined most readily by water, as nothing is ever associated with it that cannot be most easily separated, from difference of specific gravity, by roasting, pulverizing, and re-washing; excepting only the rare tungstate of iron (wolfram), when the concentrated sample must be washed with hydro-chloric or nitro-hydro-chloric acid, instead of water (which has no effect on tin oxide), as a last operation, so as to dissolve and remove this impurity. It is a singular fact that the sulphurets of lead and antimony are not found in the profitable tin veins, at least in quantities sufficient to interfere with the concentration of tin ores; which is most fortunate, as the galena would, by its too similar specific gravity, accompany the oxide of tin throughout all stages of water treatment, and both it and the sulphuret of antimony would so clog the furnace in the roasting, by their fusibility, that acid treatment would have to be resorted to for completing the process, as is sometimes the case with wolfram, which can be also used for its assay; although the antimony can be expelled by

water, and the bright lead extracted from the dry, resin-like tin, with the forceps.

Tin oxide is most characteristic for its notoriously persistent resistance to any alteration, either from unfluxed red roasting, water, or even acid washings; as well as for having a resin-like appearance, that varies from cream color to brown black, which has a peculiar rough feel under the finger and pestle. Garnet (so plentiful in this country) resembles it closely in all of these, excepting only that of specific gravity, which is most available, as it being but about 4 against tin oxide of 7, by placing any bright mineral, from about 5 upwards in its company on the concentrator, garnet can be passed over the margin, and its want of gravity may be thus, by comparison, exposed, which is in itself a good test for tin. Garnet, too, may be so easily obtained in a crystallized state, free from other substances, that its specific gravity (which is obtained by dividing its weight in the air by the difference of its weight in air and its weight in water) will inform you that it is not tin. Tin in the stone decrepitates, and garnet does not.

For example, a stone that was supposed to be tin weighs in air 80.4 grains (or ounces, etc.), which, when suspended under the scale pan by a very light thread, and a basin of water is elevated from beneath, so that the stone shall be just covered by water, it then weighs 60.3; now, the difference of these weights is 20.1, and $\frac{80.4}{20.1} = 4$; so that the specific gravity is insufficient for tin: it may be garnet.

These facts evince that if any resin-like and heavy pulverized ore, after having been roasted and re-pulverized, still resists this water treatment, it must be the oxide of tin, or the tungstate of iron, or both together, which hydro-chloric acid will further prove by dissolving the latter only.

Tin crystallizes in square prisms, or octahedrons, whilst garnet forms the dodecahedron and its modifications.

For the assay of tin by water, weigh a hundred grains (or parts), dry, concentrate, and weigh this residue, and multiply it by 78.4, and divide by 100 (by removing the decimal point two figures to the left), for the actual quantity of pure metallic tin; or, which is the same thing, and more simple, move it in the multiplier thus: .784 from 78.4. For general ave-

rage smelting returns, multiplying the weight of the residue by .72 will be nearer the realized quantity.

The gold, platinum, and copper assays are fully described in their respective chapters.

This system is much enhanced for practical value from the facts of its being a comparative measure for the waste occasioned by water, on the large scale; and, for the gold assay, it is a reliable test of what can be obtained by amalgamation, without roasting.

It will be most interesting to notice those natural and extensive parallels to these artificial methods for the concentration and collection of gold and tin for assay; as seen in the heavy water-worn washings from the alluvially formed gold and tin deposits of the world. The gold fields of California, that lie over the western declivities of the Sierra Nevada, may be taken as an example to show the general principle on which all others have been formed and washed into position; as every illustration can be seen here of all such formations. This extensive, much distorted and corrugated frontage was once entirely submerged by the Pacific Ocean, and subsequently invaded and uplifted in a somewhat irregular manner by various intermittent heaves of certain portions of the whole, by the powers created by nearer approach of subterranean fusion.

Now, we will suppose that the first upward motions were intermittent, and that a few hundred feet only of general elevation of the country was effected at a time, whilst great variations of elevation would occur at some places as compared with others; and that, during this period of uplift, the gold had been formed, as suggested in Section I, Chapter VI, or in any other manner. During the long periods of comparative stability of the country, the rivers flowing from the higher grounds would, by disintegrating the various strata, wash the nuggets of gold thoroughly clean, and which, being much heavier than all the other debris, they would be concentrated, and remain in the hollows and bends of the rivers until this valuable and much coveted metal is found by man.

Whilst this disintegration and concentration was being effected by rains, rivulets, and rivers, another *not insignificant* action was being accomplished by the powerful wash of the

ocean on the ancient, but now elevated shore, as the breaking waves from innumerable gales expended their gigantic strength on the crumbling strata, released and separated the gold, and formed the boulders, pebbles, and sands, that indicate, by such action, its probable presence.

Another uplift would form a second line, and consequent disintegration, and auriferous, pebbled shore; as would a third and fourth, etc.; and, lastly, that of the present hour, as the beach at Gold Bluffs.

The rivers that ran in *descending*, transverse courses towards these now terraced beaches, and the ocean, would be much less liable, *than such which were governed by height*, to materially change their *courses* or *positions*, unless compelled to do so by suddenly formed intrusive igneous overflowings, which doubtless sometimes prevailed.*

All of these ancient beaches and rivers must have been, at a subsequent period, again submerged by the ocean for a very long time, and then more regularly elevated; for the whole labyrinth is now covered with varying, and in some places great depths of alluvium, that could not have been formed in any other manner.

Too much has been credited to river bottoms, and crossings of the one over the other, with intervening alluvions; and too little to the more natural water-washed and weather-beaten sinuous shore, across which the rivers flowed into the ocean.

Transverse terraces of such exist in parts of the State where no present or past noteworthy river beds exist.

The gradual flowing or ebbing of ocean waters will also distribute gold or tin stone over the whole surface of a country, and leave those unmistakable evidences of such works in the shape of innumerable boulders and pebbles, amidst the auriferous and stanniferous sands.

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* If the uplifting power should again elevate the slope of the Sierra Nevada, even to the ocean, the Sacramento River would still flow through the "Golden Gate," or present river's mouth, in its prolonged course to the new embouchure into ocean; but the Seal Rocks, and serpentine beaches on either side, would be elevated to high and dry occular demonstrations of such change of level, which would not be seen so clearly if again buried by alluvium.

CHAPTER VI.

AN ALPHABETICALLY ARRANGED RECORD OF THE EFFECTS PRODUCED BY WATER AND FIRE, SOMETIMES FURTHER ASSISTED BY WATER AND CHEMICAL RE-AGENTS, ON THE MINERALS, AND SUCH OF THEIR COMPOUNDS AS WILL BE PRACTICALLY USEFUL AND PROFITABLE TO THE EXPLORER, MINER, AND METALLURGIST.

In the discrimination of the minerals, it is sometimes very important to ascertain, by comparison, their hardness; and the following list of ordinary and well known materials were first suggested by Mr. Chapman as a scale of hardness which will be found most convenient for your purpose.

1. Yields *easily* to the nail.
2. Yields *with difficulty* to the nail, or merely receives an *impression* from it. Does *not scratch* copper.
3. *Scratches copper;* and, being *equally hard*, is *scratched by it.*
4. *Not scratched* by copper; *does not scratch* glass.
5. Scratches glass *with difficulty, leaving* its *powder* on it. Yields readily to the knife.
6. Scratches glass *easily*. Yields *with difficulty* to the knife.
7. Does *not yield* to the knife. Yields *with difficulty* to the edge of a file.

8, 9, 10. Harder than flint.

The specific gravity is also very effective for discriminations of solid and homogeneous minerals, that are otherwise most similar in color, texture, etc.; and it may be ascertained as follows: Take a piece of small but strong thread, about two feet long, which place in one scale pan, and balance the lever thereto, by putting small pieces of matches or other light

substance in the other pan. Weigh the stone to be tested, which we will call 2.25 ounces; next take the stone, and fasten it by a suitably knotted loop to the middle of the previously balanced thread, and suspend it beneath the same scale pan from which the thread was taken, by knotting it over the top of the pan; and after *re-weighing* the stone, to see that no difference has been caused by jostling, etc., raise a basin or glass, that has been nearly filled with water, until the stone is just completely immersed in this water; after particularly ensuring yourself that all the air globules have left the stone, place in this pan sufficient weights to return the scale beam to balance as before, being careful to notice that the stone is still slightly submerged. Now, supposing that .72 had been required to thus re-produce the balance, the specific gravity of the stone would be found by merely dividing the *larger real weight of* 2.25 in the one pan by the *smaller re-balancing weight of* .72 in the other pan; or the *greater divided by the lesser:* $\frac{2.25}{.72} = 3.125$ the required *specific gravity;* or, in other words, "The specific gravity is ascertained by dividing the weight of a substance in air by the difference of its weight in air and in water."

For the reasons that much more extended study than generally prevails would be required for beneficial discrimination, and that the profitable minerals worked by the miner are either massive or imperfectly crystallized, I have relied on crystallography as little as possible, and then only where the form is generally well marked, and easily understood. (*See Chapters III, IV, and V, Section III, for various modes.*)

ALBITE (SODA FELDSPAR).

This mineral sometimes fills the place of the common potash feldspar, in the granite rocks.

It is more generally distributed in North America than elsewhere. It is very similar to common feldspar in appearance (apart from its crystal form, which is that of the modified oblique rhomboidal prism), and in hardness; it is, however, generally of a more tabular fracture and glassy whiteness.

It is, for your purpose, more promptly and decidedly recognized and distinguished from the common feldspar, before

the purely blue flame from the blow-pipe, which flame is changed to yellow from the presence of its soda.

The other spars of this family are more for the scientific than practical man.

ANTIMONY

Is obtained from the sulphuret of antimony, which is very plentiful on the Pacific slope. It somewhat resembles galena, being of a bright metallic lustre, with a lead-gray streak and powder; is composed of antimony 73, sulphur 27; hardness 2; specific gravity, when pure, from 4.5 to 4.6, so that, as galena, or the sulphuret of lead, is from 7.5 to 7.7, it takes a correspondingly lower position, under water treatment, on the concentrator. When one or both are present, the well known yellow sulphuret of iron (iron pyrites), of from 4.8 to 5.1, or white arsenical iron pyrites, of 6.3, will serve to show, by comparative positions, the presence of either, or both, on its upper and lower sides, when not too intimately combined. This is a ready and good practical test, when others fail to inform you with certainty.

It also fuses very readily, even in the natural flame of a candle; and on charcoal, before the blow-pipe, to a black, waxy slag, from which its voluminous white oxide arises, after the flame has ceased to play thereon, which also deposits on the charcoal at about three-fourths of an inch from the slag. These fumes may smell of sulphur, but must not afford the garlic stink peculiar to arsenic, which also gives out a white oxide, but does not fuse to the waxy slag.

It may be also fused over a lamp, or fire, in an iron spoon, when the white oxide will ascend, coat the rim of the spoon, and smell as above.

If lead is present, an alloy of lead and antimony would be the result on charcoal with carbonate of soda; some of the antimony would still volatilize. The lead oxide is yellow.

ARSENIC

Oxidizes at a low temperature, in white fumes, but less voluminous than the antimonious, which also whitens the charcoal and iron. Arsenic cannot be fused to metallic state on charcoal, nor can its ordinary ores, as those of antimony, be fused

to a waxy slag, but may be reduced to metal in a glass tube, with fluxes, by careful and close treatment.

Its ores are all dissimilar to those of antimony, when water-washed; and emit a disagreeable garlic stink, when calcined in fire, before the blow-pipe's flame, in a glass tube, or any other manner; both of which are very characteristic differences.

ALUMINA

Is an essential component of all the fire clays. It may be detected when quite dry, with great facility, by applying it, for but a moment, to the tip of the tongue, and as suddenly withdrawing it; if alumina is present in practical quantity, the sample stone will reveal its characteristic desire for moisture by adhering to the tongue.

Clays are generally white, dirty white, yellow, or pink, but sometimes from red to brown, depending on the coloring matters that may be present.

As dry chalk (which is a somewhat porous carbonate of lime, but, I think, not yet found in America) resembles it in many of these colors, as well as by slight adhesiveness, it should be also tested by fire or acids. Chalk, after it has been burned in a strong fire for some twenty minutes, or before the blow-pipe's flame for two minutes, becomes caustic, and slacks in water; it also effervesces when moistened by any strong acid; a good clay stone is not affected by either, and thereby they may be distinguished.

A more delicate test for alumina, either when free, or after it has been separated from metallic minerals, in the manner described in a former chapter on the Discrimination of Minerals by Water, is that performed on charcoal, before the tip of the blue flame, and moistened with nitrate of cobalt solution, which gives a clear, characteristic, pale blue color, after the pulverized mass has been again strongly heated in this flame, when it becomes quite cold.

BISMUTH.

The ores of bismuth are more fusible than lead, and are easily reduced to metal in the yellow flame of the blow-pipe, when fluxed with carbonate of soda, and supported by

charcoal, to a reddish white metal, which is much less ductile, or malleable, than lead under the hammer; so that a flattened button breaks into small pieces, and thus distinguishes it from lead, which also deposits a yellow oxide on charcoal.

As the *ores* of bismuth are all different to those of lead, in color as well as specific gravity, the method described in the chapter on Water Concentrations again assists to a great degree in the more certain and direct recognition of either.

This mineral is, however, scarce, and seldom conflicts with those of lead. When bismuth is dissolved in nitric acid, a copious addition of water to this solution precipitates its white oxide.

BORAX, BORACIC ACID, OR BORATES.

Any profitably valuable sample of borax (biborate of soda and water) may be detected before the oxidizing flame, by first dipping a small looped platinum wire into strong sulphuric acid, and then dropping a small quantity of the pulverized substance supposed to contain biborate of soda (or any other boracic acid compound) thereon. After some five minutes have passed, for the partial solution of the substance, place it just before the point of the small blue flame, when, if boracic acid took any part in forming the substance, the flame will be colored green on the margin.

A more exacting test is to dissolve, in a saucer, a thimbleful of the finely powdered borate substance, in twice its volume of strong sulphuric acid, for ten minutes; and, after adding about thrice this volume of alcohol thereto, to stir well, and light the alcohol into flame, in a dark place, when, if boracic acid, or *any* borate, is present, the margin of flame will be tinged green. I have thus exposed the presence of the one-thousandth part of borax. *To be certain that the borate is that of soda (borax), you must also test for soda by color of flame.*

Be sure that no copper or phosphorus is present.

The water from a lake may be tested in the same manner, but with much less of the acid. Gives blue glass with cobalt.

CHALK.

Before the blow-pipe flame, both on charcoal and in forceps, it becomes lustrous, and, after some two or three

minutes of this intense ignition, it slacks, like common burned limestone, in water.

A stone, after being exposed for one hour in the greatest heat of a common fire, likewise becomes caustic, and slacks in water.

It is of different colors, and always streaks, bruises, and marks accordingly, from being more friable than the other carbonates of lime, which, in common therewith, before ignition, effervesce in all strong acids.

Aluminous clays streak, and adhere alike to the tongue; but, under fire and acids, they act differently; for which see Alumina.

CHLORINE,

When in combination, is most easily detected with the terminal eye of platinum wire, by fusing a glass from microcosmic salt (phosphate of soda and ammonia), and saturating this glass with copper, by dipping it in oxide of copper, or into mineral copper, to be oxidized before the blue flame in this flux, until this resulting glass shows a greenish blue, cold bead. This being obtained, dip it into the liquid or substance to be examined, and replace it beyond the flame's point, in the hot current of air; if chlorine is present, it will be plainly indicated by a clear blue flame, which, though sometimes a mere border and but transient, is always distinct. This being also a test for copper, its green flame will follow.

Chlorine gas, liquid chlorine, chlorine water, and hydrochloric acid (soluble chlorides, as common salt, sal ammoniac, etc., also precipitate silver), when passed over, or into, the nitric acid solutions of silver, lead, or mercury, and unite immediately therewith, forming insoluble chlorides; which, being separated *by water treatment* from the acid, may be further distinguished by ammonia, in which chloride of silver is completely dissolved; that of mercury is thus oxidized black, whilst lead remains unaltered.

COALS.

All kinds of coals can be ignited into flame, before the blow-pipe, which continues for some time after the cessation of the blast; the flame is, however, more a measure of its

gaseous than calorific quality, as some enduring anthracites give little flame, but supply a long-continued combustion, leaving a trifling residue of unconsumed ashes.

In the bituminous coals, the more crystalline, brittle, and bright, the better the quality.

The best parlor coals are generally the worst for steam engines, and *vice versa.*

A good approximate and very quick test of its quality for household purposes may be made by carefully and gently flaming a one grain stone on charcoal, platinum foil, or a very thin sheet of iron, for a few minutes, and noting its quality of combustion, diminished weight, and composition of its residue for stone clinker or ashes.

See the Methods of Examination for Practical Men, in Chapter V, for approximate value by iron spoon, in ordinary fire; and the chapter on the Actual Assay of Coals for Commercial Purposes.

COBALT.

Fuse a borax bead in platinum wire, before the blow-pipe's blue flame; cool this bead, moisten it with water, and dip it into a pulverized sample of the ore to be tested; interfuse the ore and flux, before the oxidizing flame, to perfect fluidity; if a small quantity is present, it will show blue when hot and cold, in both oxidizing and reducing flames; if a larger quantity is present, the color will be intensified from blue to bluish black.

If the glassy bead is too dark to be recognized, break and pulverize it, when your eye alone, or assisted by a lens, will see this, or any other characteristic dark colors, much better than can be exposed by the method of flattening the hot bead with a pliers (the more difficult manipulation described by authors).

It is, when reduced to metallic powder, magnetic, as iron and nickel are; but this blue bead with borax distinguished it from these metals, as well as its prompt oxidation, and more tardy and difficult reduction to bright metal.

It has from a pink to a port wine color, when dissolved in nitric acid, which is more or less shown by the quantity present.

COPPER

Is the only red metal. A most delicate test for it, in all its metallic and mineral combinations, is to heat a small piece of the sample, held in the platinum tips of the forceps, before the blue flame for one minute; then moisten it with a drop of hydro-chloric acid (muriatic), and re-apply it before this flame; if copper is present in the alloy or mineral, the intensely blue flame from chlorine will appear first, and then the characteristic green flame of copper.

First test the naked forceps in the flame, to know that no copper is produced from the relics of former trials; and also take care that the acid does not reach and extract the copper from the "German silver" handle of forceps.

A powder may be best examined on the platinum wire, when moistened with this acid into a paste, and treated otherwise as above, or on charcoal, or in an open fire.

If you have no acid, by simply dipping the ignited and well roasted red-hot sample into a tallow candle, or any other fat, or oil, and re-flaming it, the green flame of copper can be more transiently but distinctly seen.

To examine for copper in an open fire, pulverize fine, about one ounce of the ore, intimately mix it with about half its weight of salt, and one-fourth its weight of fat, into a somewhat moist mass, and cast it into a clear, open fire; if copper is present in practical quantity, the flames of blue and green will be recognized.

Or any copper ore may be known by being first roasted in an iron spoon, or on iron; and, secondly, again roasted with salt; and, thirdly, by being placed in a clean vessel, with sufficient warm water to just cover it, when, after some time, a green solution will expose its presence.

THE COMMERCIALLY VALUABLE ORES OF COPPER ARE THE YELLOW DOUBLE SULPHURET OF COPPER AND IRON, THE GRAY SULPHURETS, THE BLUE AND GREEN CARBONATES, AND THE BLACK AND RED OXIDES.

1. THE YELLOW SULPHURET (COPPER PYRITES)—Is more universally distributed than any other, and in the "true fissure veins" of Cornwall it is the prevailing copper ore,

that has sustained the long-continued and enormous sales from that very small mining region.

It varies in composition, but may be placed at about 34.6 of copper, 30.5 of iron, and 34.9 of sulphur. Specific gravity from 4.16 to 4.3. Hardness from 3.5 to 4. It is generally of massive texture, and irregular, conchoidal fracture; of a color that varies from gold yellow to a *tarnished*, deep bronze yellow, with oxidized exterior "peacock" colors, iridescent mixtures of green, blue, and purple. Its deep yellow and peacock hues distinguish it from the arseniuret and sulphurets of iron. It is also much softer than either; it cuts crisply brittle, with less lustrous streak; takes a lower position under water treatment than gold; is dissolved by *either* of the *single* acids of *aqua regia* (nitric or muriatic), which gold resists, and does not look alike when viewed from all directions. It yields a button of copper, when fused with borax on charcoal, which, being red, is sufficiently characteristic. When dissolved in acid, it deposits copper on clean iron, easily known by its color. When fused on naked charcoal, before blow-pipe, it becomes magnetic, and gives the reaction when tested for sulphur, by any of the methods given under that heading, and, of course, the more general one for copper.

2. The Gray Sulphuret of Copper—Varies from light metal lead color to plumbago; cuts freely, but with less crispness than the yellow sulphuret. Its specific gravity is from 4.7 to 5.2. Hardness from 3 to 4.

Its composition varies greatly, both as regards the number of elements, and their respective quantities. The copper generally runs about 38.42, more or less ratioed with the following: Arsenic, 2.08; antimony, 25.27; iron, 1.52; sulphur, 25.03; silver, .83; zinc, 6.85. The arsenic, antimony, and zinc vary down to nothing; whilst the iron runs up to 7, and the silver sometimes appears to replace the copper, to upwards of 30 per cent., and occasionally other minerals happen to be present.

The general copper test will inform you of its presence, and an actual silver assay, or especial approximate tests, should be always made from all such soft gray ores, which almost invariably contain it, in silver-bearing regions.

The tests for the other minerals may be made as directed under their separate headings.

3. THE BLUE CARBONATE OF COPPER.—The blue carbonate of copper frequently but merely stains the surface of stones; is composed (from a careful analysis made by R. Phillips) of the oxide of copper, 69.08; carbonic acid, 25.46; and water, 5.46. Specific gravity, 3.5 to 3.77. Hardness, from 3 to 4.

Its color is always of distinct, showy brightness, and varies from a somewhat deep blue to Prussian blue. In common with all carbonates, it effervesces in acids. It gives the general copper reactions, and when pulverized and mixed with salt, oil, and flour, will give the blue and green characteristic flames of chlorine and copper, when thrown into a hot fire.

4. THE GREEN CARBONATE OF COPPER (MALACHITE)—Is in every way, except color and composition, similarly detected. R. Phillips gives its composition, 72.2 oxide of copper, 18.5 carbonic acid, 9.3 water.

Color, bright, strong green, to bright, pale green. Specific gravity (when solid), 3.5 to 4. Hardness, 3.5 to 4.

5. THE BLACK OXIDE OF COPPER—Like the carbonates, is invariably found above the water-line. It has a soot-like appearance, is friable, somewhat unctuous, and, like the black sulphuret of silver, soils the fingers.

It is also frequently seen in the shallow portions of Cornish veins, although more in indication than quantity. It is more easily discriminated than the other coppers, as all that is necessary is to moisten the tips of your finger and thumb, to rub them thereon, and apply it to your lighted candle, so as to recognize the characteristic green flame of copper. It is also most easily dissolved by acids, and reduced on charcoal by blow-pipe, or in crucible. It will not stand the water treatments, on the small or large scale.

6. THE RED OXIDE OF COPPER—Is sometimes found alone in workable quantity, but is generally associated with the shallow carbonates, or ride a deeper development of gray ores.

It may be easily detected by the foregoing methods; and being of simple and rich composition—copper 88.5, and oxygen 11.5—it can be as readily assayed.

It will not stand against water-washings, without considerable wastage. Nitric acid gives a green solution with this ore, and deposits copper on iron. Cinnabar is insoluble, and freely volatilizes in fire. Red silver shows no color with nitric acid, and precipitates plenteous white curds with salt. Red ochre of iron gives no copper reactions.

There are some fifty other different ores of copper, that partake more of scientific interest than practical value, as they are not found anywhere in sufficient quantities to pay for separate extraction.

FELDSPAR.

There are four kinds of feldspar: Common feldspar (orthoclase), albite, labradorite, and nepheline. They almost entirely compose the porphyries, and are present in the various granites, as explained in Chapter I, Section I, in a crystallized condition, where they may be more advantageously studied; as also in mixed, disintegrated condition in the fine-grained, re-formed Azoic rocks described in Chapter II, Section I; as also in lavas. The miner not requiring a very close analysis of these spars, beyond their visual recognition, I must save the considerable space that these would require for illustration, and refer the curious to those works that are particularly devoted for discrimination of all the minerals. For the miner's purpose, common feldspar (potash feldspar) is most advantageous, and which he can study, when assisted by a good glass, in the granite folds of the book of Nature, sufficiently well for the purpose of recognition, that he may know it from its associate, quartz. (See Albite, at page 172, this chapter; and the Composition of Primitive Granite, Section I, Chapter I, at pages 22, 23.)

FLUOR SPAR

Frequently accompanies the minerals of copper and lead; it crystallizes in the cubical system, and varies in color from a watery white to yellow; from sky blue to greenish blue; and from pink to amethyst, to dark purple, approaching to black. It is very brittle, does not scratch glass, nor crystallize, as quartz; and is not scratched by the nail. On being heated before the blow-pipe, or in any open fire, it may be seen to

burst violently, and scatter, during a crackling noise, into numerous pieces, individually exhibiting peculiar phosphorescent lights, that vary in color, as the mineral is composed, from blue to green, which continue for some time after it has escaped from the fire. This last is a superior and ever ready test, as a stone can be cast even in the sage-bush fire (during darkness is best), and tested in one minute, which appearance, once seen, will never be forgotten.

GOLD

Is generally found in the metallic state; in fact, for practical purposes, it may be thus considered.

It is always more or less alloyed with silver and copper, and its color and value vary accordingly.

Pure gold is yellow, is unchanged by any single acid, but is dissolved in nitro-hydro-chloric acid (called "aqua regia," which is composed of from two to four parts of hydro-chloric acid, added to one of nitric acid); it should leave no precipitated residue of chloride of silver.

It is much more ductile than any metallic alloy of similar appearance, and flattens under pressure to an almost unlimited size, without cracking its edges. When a supposed gold button is recupelled with lead, it should not lessen its weight but in a slight degree, or base minerals will have been present.

In the stone, it is best known by giving the same metallic yellow lustre in all directions, or the same to the eye when the stone is turned round during observation, whether it is dry or wet. Other yellow minerals are lustrous in certain positions only, or vary in different directions, as reflected from bright faces.

In the absence of other tools, a very efficient and ready test may be extemporized by taking a transparent wine or whisky bottle for a concentrator, into which place 1000 grains of finely pulverized quartz; after the bottle is half-filled with water, securely corked, and well shaken, to sink the float gold and arouse the debris, the dirty water may be carefully poured away; repeat this half-filling, shaking, and pouring, until clear water passes away; next concentrate, by holding the bottle by the neck with the right hand, as you would a

horn, and allowing the greater part of the lighter debris to pass towards you through the neck, and observe if any gold lies under the heavier residue, by looking up through the glass. (See the chapter on the Gold Assay, for greater quantitative nicety, by extended manipulations.)

In water treatment, it occupies the head, and resembles in appearance nothing closely but yellow mica, which is, however, very light, and washes away; or yellow, bright brass chips, or spelter, which should not be there but by chance, and can be tested by fire, by darkening, or are removed by acids. (See, also, Chapters III and V, Section III.)

If you have any doubt about its being gold, after either of these trials, it is not gold.

GRAPHITE, OR PLUMBAGO.

Graphite is composed of carbon, with from about one to three per cent. of iron, which varies its color from that of polished platinum, to a dull lead gray. It is of a flaky appearance, easily scratched by the nail, perfectly infusible before the natural blow-pipe flame, and insoluble in all acids. The darker kinds resemble the less frequent molybdenite (sulphuret of molybdenum) in appearance; but the latter is known by the sulphur test, lessening its weight before flame, and by partially dissolving in nitric acid. Graphite is very much like native amalgam, and, when rubbed by gold, this metal is whitened in the same manner as if amalgamated; but it may be rubbed off, and is not volatilized by the flame, as mercury would be.

Plumbago contains a greater and variable amount of iron, not exceeding ten per cent. Its quality is governed by this proportion, its freedom from earthy impurities, and more substantial texture.

It marks as the lead pencil, stands fire, and is little affected by acids.

HORNBLENDE.

This mineral is variously found, both crystallized and massive, as well as in syenitic granite; the hornblendic slates; hornblendic feldspar, which is the fine-grained rock called greenstone; and hornblendic albite, which is a some-

what similar rock called diorite; as well as in numerous other more complicated rocks, that do not in any way concern the miner. It is ostensibly a silicate of lime and magnesia, but contains various mixtures: about fifty per cent. of silica, with magnesia, lime, alumina, the protoxides of iron and manganese, hydro-fluoric acid and water, in consecutively diminishing quantities. Here the iron, as in mica, darkens the specimen. The chief difference is that mica contains potash, instead of lime and magnesia.

With the assistance of a lens, and knife, you should become familiar with its general features, as seen in the granite called syenite; and illustrate on charcoal, in the blowpipe's yellow flame, that hornblende fuses to a globule, that varies in color from green to black; whilst mica, which may be taken from granite proper, is thus not only infusible, but becomes opaque, and much whiter. Remember, too, that, although cleavable, it is more horn-like and tough, as well as being non-elastic, and less glassy than mica; mica is also softer.

Specific gravity from 3 to 3.4. Hardness from 5 to 6.

These are sufficient tests for your purposes of mining. (See numerous authors on general compositions of all the diversified minerals, for other combinations.)

IRON

Is distinguished from nickel, which is also rendered magnetic by fire, by the borax bead of nickel being, instead of bottle-green, violet when hot, and reddish brown when cold.

It differs from cobalt most palpably in the blue color produced by this mineral, when fused with borax.

The rust water test for iron, described in the chapter for Practical Men's Discrimination, may be used, when a violet to reddish brown or a blue bead appears, to see if iron is also present, and the carbonate of soda test for manganese.

Iron is difficult to reduce to metal, in a short time; whilst nickel and cobalt, with carbonate of soda, are easily and promptly reduced: the first to a white magnetic metal; the second to gray magnetic powder. Be careful that no iron, abraded from an iron mortar, is present; bruise in brass, or between stones.

After fusion, it will be advisable to pulverize, and resort to the water treatment system, described at foot of page 152, which will pass off the soluble portions of the flux, and the lighter debris; when the resulting metals may be dried over a tea-kettle, and examined by magnet or lens.

THE COMMERCIALLY VALUABLE ORES FOR IRON ARE THE ARSENIURET, CARBONATE, CHROMATE, HEMATITES, SULPHURETS, AND MAGNETIC VARIETIES.

1. THE CARBONATE OF IRON—Free from other carbonates, is distinguished from the rest of the iron ores by nitric acid, which causes it to effervesce when in a pulverized condition. It dissolves slowly. It is, when pure, composed of protoxide of iron 62.07, carbonic acid 37.93; but, as it is often mixed with manganese, lime, magnesia, and alumina, as well as mechanically associated with quartz, little reliance can be placed on these figures for practical purposes.

Its specific gravity ranges from 3.6 to 3.85. Hardness from 3 to 4.6.

Generally massive and somewhat foliated, but at times crystallized in rhombohedrous and hexagonal prisms, occasionally with curved facets. Sometimes found in irregularly blistered, curvilinear forms. Natural appearance sparry, vitreous, colored from yellow to gray, or from reddish brown to brown, which changes by exposure to black on its surface. The streak and powder of the black variety is brown; that of the others, as themselves. It attracts a very delicate magnetic needle; blackens before the blow-pipe's flame; and, when intensely heated within its yellow flame, it becomes more magnetic, and is then attracted by a magnet.

2. CHROMATE OF IRON—May be distinguished from other iron ores by the emerald green color of its glass, when fused in wire, with borax, or phosphate of soda. This color is more easily obtained, and in both flames, by a very small quantity, than would be generally the case with iron which gives a bottle-green in the reduction flame only; when in excessive quantity, the glass of iron is reddish brown. The iron bead in the platinum wire, being again fused with a very small piece of tin, becomes copperas green; the chromium

bead being unaltered by tin. By taking the same small quantity of any other iron ore than the sulphuret (which requires longer time), and fusing it in a similar manner with borax, the beads may be more readily distinguished, and the presence of any chromated ore be established with greater certainty by comparison.

When any chromic ore is mixed with about equal parts of carbonate of soda and nitre, and fused, either on clean iron or platinum foil, over the clear flame of any lamp, further intensified by upward blast of blow-pipe, a very small quantity can be detected by its forming an effervescing sulphur-yellow mass when hot and when cold.

This may be also performed in an iron or platinum wire, before the blow-pipe's clear flame.

These colors are best compared after coarse pulverization.

If you have no better convenience, a piece of clean iron may be warmed in a hot fire to bright redness, and the intimate mixture sprinkled thereon, when, if it is a chromate, this yellow mass will be again produced.

A piece of small hoop iron, or crinoline steel, of about two feet long, may be conveniently used, by first dipping one end in water, then into the pulverized sample, intimately mixed with fluxes, and, after warming it to bright red in the fire, the color may be recognized, either at sight or when pulverized. This may be also performed on bone-ash cupel, before blow-pipe, or in a clear, hot fire; green patches may appear around the margin of the fused mass, where the soda has probably combined with the phosphorus from the phosphate of lime, and also giving the phosphate of soda bead reaction, as before explained.

The addition of nitre to carbonate of soda, although wonderfully effective for intensifying and creating a color where none would otherwise appear, when only a minute quantity is present, is not imperatively necessary for detecting the practically valuable ores, which the carbonate of soda would sufficiently expose. Long firing is required to destroy the yellow color, when produced.

It physically resembles some of the from reddish brown to black hematite ores, excepting that it shows silky facets, which are also frequently conchoidal, and of a more earthy

transverse fracture. When pure, it is unaffected in color or shape before blow-pipe or in tube, but becomes magnetic. It is nearly always associated with lime, magnesia, or alumina. Specific gravity from 4.3 to 4.6. Hardness said to be 5.5. I have a fine sample now before me, which is not so heavy, being but 3.9, probably cellular; and its hardness does not exceed, in the fractured parts, 4.5. Composition irregular; generally contains about fifty per cent. of oxide of chromium, and thirty-five of the peroxide of iron; the remainder variously composed of lime, magnesia, and alumina.

Chromate of potash may be formed by fusing this mineral in a crucible, with caustic potash. This, dissolved in a small quantity of water, and filtered, is a mutual test for lead and itself, in acid solutions, which may be sometimes resorted to for positive proof of its presence.

3. Hematite Iron Ores—Are from a red to a brown color, approaching to black on the faces of fracture, but not exposing much appearance of crystallization; scratches and bruises to a red powder, which, being very friable and somewhat unctuous, stains the fingers, and forms a red mechanical solution with water, that favors to a remarkable degree its sepation from tin ores, with which it is frequently associated in Cornwall; forming red rivers, that reach into and color the sea for miles in extent.

Specific gravity from 3.5 to 4. Hardness, maximum, 5.5, varying downwards to as low as 3, according to the extent of disintegration, decomposition, etc. These ores generally produce about sixty per cent. of cast iron, and as high as sixty-four has been obtained, depending on gangue, etc. Blackens and becomes magnetic before the blow-pipe; does not effervesce in acids, as the carbonate; pulverizes to an impalpable red powder, which may be all passed away, suspended in water before and after ignition, and gives, when enclosed in platinum wire, with borax, in the yellow flame of the blow-pipe, a bottle-green glass; not the emerald green of the chromated iron, last described. It gives out constitutional water, when heated in a close or open test tube, above the boiling point of water, to low redness. This must not be confounded with mechanical moisture; and therefore it should be thor-

oughly dried in a clean covered basin, placed as a lid over a tea-kettle, or coffee-pot, of boiling water (if you have nothing better), until quite dry.

4. Magnetic Iron Ores (Native Magnet)—Are sufficiently characterized by their singularly inherent or natural magnetic and polar powers, and by being iron-like black, and streaking and pulverizing black.

It is found both crystallized in octahedrons as well as dodecahedrons, and more frequently massive in extensive beds.

Specific gravity 5 to 5.1. Hardness from 5.4 to 6.5. Composed of both peroxide and protoxide of iron; the iron being theoretically 72.4 per cent., oxygen 27.6. It is brittle, but stands water (before roasting) better than the other commercially valuable ores of iron.

A fine smelting ore, which is very generally found in large quantities throughout the world, in nearly all formations.

5. Magnetic Iron Pyrites (Sulphuret of Iron).—It varies from yellow to copper and flesh color, and is generally found massive.

Large quantities of the darker varieties were taken from the Great Onslow Consols Mine, Cornwall, which often puzzled the miners, who were unaccustomed to separating it from copper, by the light of the candle, before it was drawn to the surface. It tarnished by exposure to closely resemble the horse-flesh ores of copper, which may, however, have been facilitated by the presence of a natural solution of copper, which was so strong as to be profitably beneficiated at the surface, by precipitation on metallic iron.

It cuts more freely with the knife than common iron pyrites, its hardness being from 3.2 to 4.4, and specific gravity from 4.4 to 4.6. It attracts the magnetic needle slightly, which the common iron pyrites do not do, and fuses when completely enclosed by the yellow (reduction) flame, to a black globule, which is attracted by the magnet, thus differing from copper pyrites, and bruises to a yellowish powder; whilst, before the blue, oxidizing flame, it afterwards bruises to red oxide of iron. Composed of iron 60.5, and sulphur 39.5.

6. Common Iron Pyrites (Bi–Sulphuret of Iron)—Is of yellow color, and metallic lustre in mass and in powder; crystallizes generally in cubes, its modifications, and derivative forms; but sometimes it takes the place of other minerals' vacated forms, by filling such cavities; and also massive, or speckled, in quartz veins, etc., etc.

Composed of 46.7 per cent. of iron, and 53.3 of sulphur; its specific gravity is from 4.8 to 5.1, which alone distinguishes it from the magnetic variety; and its hardness from 6 to 6.5. It strikes fire with steel, and scratches glass freely, which the magnetic iron pyrites will not do; nor do common iron pyrites affect the magnetic needle. It gives the various reactions for sulphur, and, heated before the blow-pipe on charcoal, it volatilizes sulphur, recognized by its smell; and affords a mass, or, if in very small quantity, under a perfect reducing flame, a globule, which are both attracted by a magnet.

The sulphurets of iron are profitably worked for gold (which they invariably contain), in all gold quartz regions, as well as in some districts for their sulphur, by forming sulphate of iron, sulphuric acid, sulphur, etc.

7. Arsenical Iron Pyrites.—The Practical Analysis of Dr. Thomson, alluded to in the Elementary Treatise on Mineralogy, by William Phillips (to which work I am indebted for many others), gives 33.98 of iron, 45.74 of arsenic, and 19 of sulphur; the theoretical quantity being 33.57 iron, 45.53 arsenic, and 19.9 of sulphur. Specific gravity 5.7 to 6.3. Hardness 5.5 to 6.

It crystallizes in variously modified right rhombic prisms, which, in practice, are seldom seen to further advantage than to show that the sharp angles are mostly turned outwards, forming aggregated groups different to the sulphurets of iron. It is nearly white, unless tarnished to light yellow; of very bright metallic lustre, which, combined with its hardness, scratching glass, striking fire with steel, and garlic stink, separates it from the minerals that otherwise would too closely resemble it.

A small piece may be rendered magnetic by being placed on charcoal, and enclosed for some time in a steady and hot reducing flame.

8. Tungstate of Iron (Wolfram)—Although of no commercial value, is often a source of much annoyance to the tin miner; for, being non-volatile, and of similar friability and weight; fire, pulverization, and water, all fail to effect its separation: and, as the smelter requires the tin oxide in all its purity, the millman has to rid it from the incumbrance by dissolving it in hydro-chloric acid.

It is composed of 74.66 of tungstic acid, 17.59 protoxide of iron, 5.64 protoxide of manganese, and 2.1 of silica, a comparatively pure specimen, as analyzed by Berzelius; the silica being probably accidental. Specific gravity from 7.1 to 7.4. Hardness from 5 to 5.5. Its color varies from dark brown to black; the fractured faces are always lighter, and the streak reddish brown.

Being of higher specific gravity, less volatility and friability, than any mineral which it resembles in color and general appearance, excepting tin, it may be practically recognized and separated by the water and roasting treatments; and from tin it can be readily parted by being dissolved in hydrochloric (muriatic) acid, and re-washing. Tin oxide is insoluble in all acids.

It is massive, and crystallized in rectangular prisms; whilst tin is mostly in quadrangular prisms, that are terminated by four-sided pyramids. It is readily fused with borax, yielding a green bead, but which does not act on the magnet, nor produce either a white oxide, or metal, as tin does. Different to most iron ores, it decrepitates like tin. With microcosmic salt, it yields a red bead. The most certain test is that of acid for the tin miner's guarantee against error, and for ascertaining the actual quantities of each that may be present.

KAOLIN

Is a peculiar clay, composed of silica, alumina, peroxide of iron, and water. It has been used most successfully by the Chinese, in the manufacture of the porcelain called "china," in which they have, from superior skill, better natural material and colors, not only preceded, but surpassed all nations.

It is chiefly found in the hollows, lying on the flanks of granite hills, being the resultant residue from the washings

of this rock, after partial decomposition and disintegration have released the potash that passed away in the water.

It is still found in China, in great abundance, and of better natural quality than elsewhere. France, Saxony, and Cornwall are the principal European sources. It is found in Cornwall, in several districts, of white, yellow, and pink colors, and is quite an extensive and profitable business.

The mode of extraction and preparation for the market is most simple, and consists of shovelling and stirring the broken debris in water, to cause the impalpable kaolin debris to be suspended in the water, which is conducted into several suitably formed catch reservoirs, provided with flushets for shutting off the water when each pit is full, so that the clay may settle to the bottom, which is, after the clear water has passed away, repeated, until the white mud becomes some six inches deep, when, after it is sufficiently dry, it is cut into cubes, and further dried for the market by the summer's sun, and placed under sheds, to be shipped when convenient. It is also the base of fire-resisting bricks. The fire will prove their quality, after moulding a small brick. (See, also, Alumina.)

LEAD.

Lead can be reduced, even on unfluxed charcoal; but much more readily with its weight of carbonate of soda. It deposits oxide on the charcoal at about a half-inch from the test sample, which is orange yellow when hot, and sulphur yellow when cold. Bismuth deposits a very similar oxide, so that they are better known from the physical characters of their minerals and metals. Metallic lead is easily recognized by its well known color, manner of fusion, rainbow streaks when in fluidity before the oxidizing flame, the crystallization and color of its oxide on the ash, by its flattening to a very thin disk without fracturing the edges, and by its toughness when cut or repeatedly bent. Metallic bismuth is brittle.

Lead may be dissolved in strong vinegar, or by dilute boiling nitric acid (say water 1, acid 1); and, when thus in solution, it is precipitated by dilute sulphuric acid to a sulphate, or by hydro-chloric acid to a chloride, which should not be affected in any way by ammonia. These wet tests are entirely different to bismuth; which see.

The minerals of lead (both galena and the carbonate), are also, under water treatment, very different in color and appearance to those of bismuth, which serve, to a remarkable degree, for discriminating what are otherwise similar.

LIME

May be recognized, in its commercially valuable compounds, as follows:

First ascertain, by applying the blow-pipe's flame to a small piece, not larger than a pin's head, when held in the forceps, that it becomes luminous on its sharp edges; that the flame is transiently bordered by pink (which may be shown more distinctly when moistened by hydro-chloric acid), and if it is infusible, for these are some of its qualities; and if, after it is cold, it has the peculiar caustic lime taste, and slacks in water like the commercial burnt lime.

Next, it differs from quartz, and all the flinty compounds, by being perfectly infusible with carbonate of soda, when subjected to intense heat on charcoal; the soda passing into the coals, leaves the lime on the surface, unfused; whilst quartz, and the varieties of silicious stones, would be fused thereby to a bead. The carbonate of magnesia is also thus infusible, becomes luminous, and caustic, but lacks this color, and does not slack in water. Lime carbonates effervesce in strong acids. Lime sulphate may be detected by the test for sulphur, as well as by its peculiar action before heat, of immediately swelling to a flour-like white, and crumbling into "Plaster Paris." (See Chapters III and V, on examinations by blow-pipe, and ordinary testings for practical men.) If you suspect that it contains both lime and magnesia, test for magnesia. Quartz scratches glass; these do not.

MAGNESIA.

The best test for magnesia, when free from metallic oxides (and, if it is not so, avail yourself of the water methods, fully described in Chapters III and V, for separation), is that of first roasting the sample on charcoal, before the blow-pipe's blue flame, and then moistening it with a drop of the nitrate of cobalt solution, and re-flaming at intense heat for a short time; after which, if magnesia is present, a brownish

pink will be the result, when the mass of slag becomes quite cold. Observe that the sample was not thus colored after the first ignition, by heat alone, or that this change of color was really produced by the solution.

It is infusible before the blow-pipe, on charcoal, both *with* or without carbonate of soda, and its hard kinds are thus distinguished from quartz, and the flinty stones, which, though infusible alone, are quite fusible with carbonate of soda; so that, when a small piece of the former is mixed with carbonate of soda, and intensely heated on charcoal, the soda sinks into the coal, and leaves the magnesia unaltered on the surface; whilst quartz, and the other silicious stones, are thus fused into a glass ball. It does not now slack in water, as lime; which see.

Dolomite, a metalliferous rock, composed of about equal parts of lime and magnesia carbonates, is so similar to some of the lime rocks, that the blow-pipe tests are scarcely sufficient for certainty, when the following wet test will serve your purpose: Weigh one hundred grains of the pulverized sample, which place into a porcelain dish, basin, or tea-cup, and add about thrice its volume of sulphuric acid thereto. This acid will decompose the carbonates, and the sulphate of lime, thus formed, being insoluble in this acid, will lie at the bottom of the vessel; whilst the sulphate of magnesia remains in solution. After allowing it to settle, pour off, or filter, this solution into another basin, and evaporate this sulphate of magnesia over the chimney of a common coal oil lamp to dryness. The first may be well water-washed, dried over the tea-kettle, and weighed as sulphate of lime; and the second may be moistened with water, and recognized by the peculiarly disagreeable, bitter taste of Epsom salts. If no other earths or minerals were present, its quantity may be also ascertained by calculating from equivalent numbers, founded on the quantity of lime, or its corresponding carbonate, the proportionate remainder of the carbonate of magnesia. These crystals may *now* be tested as before.

MANGANESE.

These ores are found (commercially valuable) as oxides, which are from reddish brown to black, varying from earthy

to a resinous appearance, lacking metallic lustre, bruising and streaking, either the same or a lighter shade of the color. It resembles more or less in appearance some flinty compounds, tin ores, the friable garnet and spinel, some iron ores, and certain magnesian rocks. It is readily distinguished from the flints, tin stone, garnet, and spinel, by its inferior hardness (not scratching glass), and from all minerals by affording a surprisingly delicate characteristic greenish blue, when fused with carbonate of soda, either on platinum foil over spirit lamp; in platinum or iron wire, before the oxidizing flame; or in an iron spoon, in an open, clear fire; this is by far its best reaction, which may, however, be further corroborated by fusing it with borax in the same manner, when the hot glass will show from violet to amethyst, and the cold glass reddish violet, approaching to purple, which appears almost black when in excess.

An addition of a very small crystal of nitre increases the color, when minute quantities are present; and pulverization of the bead exposes the thus modified and true color of the glass, when in excess, much easier and better than flattening with forceps, so often recommended. By completely enclosing the borax bead in the yellow flame, this color disappears. As nickel gives a too similar bead with borax, the carbonate of soda test is also necessary, for absolute certainty.

Manganese, boiled with sulphuric acid, when in very small quantities, may be detected by adding litharge, which changes the solution to pink.

MERCURY.

Its principal ore is the sulphuret (cinnabar), which is from light to dark red, always pulverizing very easily, and more like a drug than mineral, to bright carmine red. Distinguished from the red iron ores by this, and by wholly or partially volatilizing on charcoal or on red-hot iron, and by losing its red color at a moderate heat, as it is more or less pure, instead of becoming red and magnetic under an intense heat; and from the red clays by this volatility, by not adhering to the tongue, and the test of nitrate of cobalt solution

for alumina; from red copper and red silver, by not giving the green flame, nor metallic silver.

All the compounds of mercury, when fused with carbonate of soda, at a moderate heat, are decomposed and reduced to the metallic state, which, arising in fumes, are again speedily condensed, at a slight decrease of temperature; so that if cold gold is placed therein, the amalgam thus formed on its surface evinces the presence of mercury. This may be tested in a close glass tube, held over a spirit lamp, or over a clean piece of red-hot iron; and either a small strip of gold may be held in the tube for amalgamation, or the cold tube may be rubbed with a stick of clean wood, an iron wire, or glass rod, when the bright mercury, by being thus scraped into ridges, may be seen on the glass. This may be varied to suit your tools, as in an iron spoon, in a tea-cup, etc., etc., or as described at pages 166 and 167.

Cinnabar bruises very easily, giving to the water a bright and peculiar carmine red, which passes all away with the water into the second vessel, by repeated pulverizations, and must be there estimated; whilst the lighter and less friable gangue residue can be separated by being swept over the margin, as convenient. Native amalgam of mercury and silver may be known by the amalgamated gold surface, which must not rub off as graphite would, but pass away by heat alone.

The red solution may be filtered, dried, and weighed; or allowed time to settle, then decanted, dried, and weighed.

MICA.

This mineral is widely distributed. Associated with quartz and feldspar, it forms the dark, glassy constituent of the granites; and in more minute scales, seen by a lens, the similar ingredient of mica schist (metamorphosed crystallized slate); as well as in numerous other mixed formations from primitive elements, in the secondary rocks. It is generally colored by iron from light silvery gray to brownish gray, or from olive green to black, but is sometimes golden yellow. The miner may study it sufficiently, in true granite, by the use of a sharp knife, a lens, and blow-pipe; he will see that

it is easily cloven into very thin scales, which are elastic (hornblende is non-elastic); it is infusible, and whitens before blow-pipe (hornblende is thus fused to from green to a dark green and black globule); it is also softer than hornblende. Specific gravity 2.8 to 3. Hardness from 2 to 2.5.

Transparent plates of mica have been found in the United States of America, two or three feet in diameter.

The cleavage is parallel to the facets, and it crystallizes either rhombic or hexagonal. Its composition but differs from hornblende by having potash instead of the alkaline earths, lime, and magnesia. Talc is more soapy, and its scales are not elastic. Gypsum bruises white, whitens by heat at a much lower temperature, crumbles into "Plaster Paris," and gives the sulphur reaction on silver, when fused with carbonate of soda.

MOLYBDENITE.

Sulphuret of molybdenum is of very similar appearance, softness, and color, to graphite. It is, however, a rare mineral, and named here more to distinguish it therefrom than for profitable usefulness in itself.

Its general color is lead gray, and thus, it is more constant, than graphite. It is partially soluble in nitric acid, leaving a gray residue. It is also more than twice the specific gravity, being about 4.6. It gives the sulphur reactions, and diminishes almost one-half its weight on being roasted. Graphite does neither; which see.

NICKEL.

This mineral is profitably obtained from the arsenical nickel, called "copper nickel," its color being a lustrous pale copper red, with a somewhat darker streak and powder. When water-washed, its high specific gravity of about 7.5 favors its examination and estimation, which is further facilitated by its peculiar appearance and speedy reduction to white metallic, magnetic scales, with carbonate of soda on charcoal, which is not coated with the white or yellow oxides of antimony, zinc, tin, lead, or bismuth. It may be otherwise detected, in all forms, better by its differences with those minerals that are also subject to be reduced to their

magnetic actions, as iron, manganese, and cobalt. In common with iron and cobalt, it is magnetic; but the color of the borax bead with nickel being reddish brown in oxidizing flame, that of iron bottle-green, and cobalt blue, are all sufficient with these. Manganese very often contains iron, which gives the magnetic action to the sample, the color at the same time being, with borax, too similar to nickel; so that the collateral tests of carbonate of soda, both for the greenish blue bead from manganese, and reduction to the magnetic scales of metallic nickel on charcoal, must be resorted to, for greater surety. The fused slag must, for the latter test, be finely pulverized, and examined by the water concentration method, assisted by a magnifying glass, as fully described at pages 152 and 153, for fire and water treatments.

PETROLEUM

Is a reddish brown, oil-like liquid, lighter than water, and somewhat similar to tar, which is more or less found in, or flowing from, natural wells, in all countries, but more particularly in and around large or small coal fields. It has naturally a somewhat disagreeable bituminous odor; it is inflammable, and, during combustion, emits a thick black smoke. The black residue being weighed, gives the quantity of uninflammable matter present, and its comparative quality; which residue, on being heated to redness in a clean vessel, further exposes the kinds and quantities of the non-gaseous, inorganic remainder.

Its composition varies from accidental ingredients; but it is essentially a hydro-carbon. By distillation, it produces naphtha, a colorless or slightly yellow liquid that floats on water, composed of carbon 82.2, and hydrogen 14.8, which, by exposure to air and light, thickens, and again becomes brown petroleum; which latter, by further exposure, and oxidation, becomes elastic bitumen, and compact bitumen, of specific gravity from 1 to 1.6, and earthy bitumen, or asphaltum, when earths, etc., become mixed therewith.

Good practical tests are, boiling the sample in water, to ascertain if it will separate and float on the surface; careful ignition, for quantity and quality of flame; and subsequent

red heat of residue, when an approximate of value may be promptly known, by comparative residual percentage.

PLATINUM.

Always found in the metallic state; accompanying gold in surface washings, but not in veins.

Similar in texture and appearance to nickel and malleable iron, but just somewhat more silver-like than the latter; it is not attracted by the magnet, and is thus distinguished from them. Insoluble in sulphuric, nitric, or hydro-chloric acids, which separate it from all the base white metals and their alloys. It is soluble in aqua regia (which is composed of one part nitric acid, and from one to four of hydro-chloric acid), and again precipitated yellow by potash or ammonia; chloride of ammonia (sal ammoniac) also precipitates it yellow, which can be reduced by heat to spongy platinum.

This metal is infusible with the ordinary heat produced in furnace, or before the blow-pipe, both with and without fluxes; but it can be readily fused in the oxy-hydrogen blow-pipe flame.

PRECIOUS STONES.

THE DIAMOND (which is pure carbon)—May be considered to stand foremost amongst the commercially valuable gems. It is either transparent and colorless, or variously colored, and consequently less transparent, as yellow, blue, green, rose, brown, and very rarely black.

It is the hardest of all gems, 10; specific gravity from 3.48 to 3.55; and always found crystallized in octahedrons, dodecahedrons, and numerous corresponding additional facets, which facets nearly always differ from other gems by being slightly convex. Where the edges of the crystal are imperfect, a lens shows that they have been broken, and not worn, off.

It may be best known by its scratching the hardest flint, as well as all the gems; by being infusible, and unchanged (within any reasonable time) before the blow-pipe, even with fluxes (quartz and silicates being more or less fusible with carbonate of soda); by being insoluble in all acids (even hydro-fluoric, which readily attacks quartz and the silicates);

by its specific gravity; brilliant reflections of light; and by becoming electric in its natural condition, when rubbed on cloth, shown by its attracting small pieces of paper or other suitable substance (which no other gem will do before it has been polished by artificial means). It is mostly found in alluvial washings, in similar positions to gold, platinum, etc.

EMERALD (BERYL)—Crystallizes in long hexagonal prisms, with singular terminations (but not mitred from side facets, as quartz). Color, green; *beryl* being sometimes from blue to yellow; lustre vitreous; from transparent to translucent and opaque. Hardness from 7.5 to 8. Specific gravity, 2.65 to 2.75. Brittle, with conchoidal (uneven) fracture. The transparent kinds, in small pieces, become clouded before the flame of the blow-pipe, and with increased, continued heat, assume mother-of-pearl appearances.

Dr. Thompson gives their composition as 2 atoms tersilicate of alumina, and 1 atom tersilicate of glucina; the former is colored by the oxide of chromium, and the latter by the oxide of iron.

It differs from green tourmaline in hardness and crystallization, and from euclase and topaz by its uneven fracture, they possessing more regular cleavage.

PRECIOUS OR NOBLE OPAL—Is a beautiful, milk-colored gem, that also exhibits, in the light of day, a changing interior play of the pearl-like colors, green, blue, yellow, and red, which become yellow by transmitted light, and are sufficient in themselves for the recognition of this peculiar stone.

It is composed of soluble silica, and a varying quantity of water: sometimes as much as ten or twelve per cent.

Its specific gravity is about 2.2, but varies with the quantity of water present. Hardness from 5.5 to 6.5.

It is not so hard as quartz. It is infusible alone on charcoal, but fuses with effervescence, with carbonate of soda, to a clear bead. It may be dissolved in boiling hydrate of potassa, and again precipitated by sal ammoniac. Gives off water, when heated in glass tube or before the blow-pipe, that may be caught and condensed in a glass tube.

SAPPHIRE (CORUNDUM).—This gem, when perfectly white, seems to be pure alumina (aluminum 53.29, oxygen 46.71).

It, however, consists of two precious varieties, the sapphire proper, and the oriental ruby. The former has a specific gravity of from 3.9 to 3.97; the latter of somewhat less. There is also a common corundum, and ordinary emery.

"Sapphire has obtained several names, dependent on its color and lustre: the transparent or translucent, *white sapphire;* the blue, *oriental sapphire;* the red, *oriental ruby;* the yellow, *oriental topaz;* the green, *oriental emerald;* violet, *oriental amethyst;* the greenish blue, *oriental aqua-marine*; with pearly reflections, the *chatoyant* or *opalescent* sapphire; when transparent, and with a pale reddish or bluish reflection, *girasal sapphire.* Some, when cut *en cabochon*, present a silvery, star-like opalescence of six rays, in a direction perpendicular to the axis; this variety is termed *Asteria.* The same crystal occasionally exhibits the union of two or three of these different colors."—*William Phillips.*

It occurs in variously terminated six-sided prisms, and stands at 9 (being next to the diamond) in the scale of hardness. It is unaltered, even when in powder, before the blowpipe's flame, on naked charcoal; but, when fluxed with borax, it fuses with difficulty into a colorless glass. It is unaffected by acids. Transparent pieces, when polished, become electric by friction, and retain this property for some time. It may be distinguished from the diamond and zircon by specific gravity, crystallization, hardness, and fusibility; which see.

The oriental ruby is most beautiful and valuable. It varies from a rose to a blood-red color, of similar crystallization, and the other enumerated features. In addition to these, it becomes green when highly heated, and returns to its original color when cold. The green sapphire is thus unchanged.

Corundum stone and emery are of but ordinary beauty, and low commercial value.

TOPAZ—Is a stone of inferior hardness (8) to all the preceding, excepting opal, and of specific gravity from 3.49 to 3.56. Color pale yellow, or various pale tints of blue, green, or red. Lustre vitreous. Streaks white. Not affected by acids. Infusible without flux, but with borax it slowly melts into a transparent glass. Occurs massive, rounded, and in right rhombic prisms, in primitive rock. It becomes electric

and polarized by being heated to redness, and retains shape and transparency; whilst tourmaline, which also becomes electric, whitens, and swells; but its specific gravity is from 3 to 3.1. Its bright transverse fracture is also a distinguishing feature, against the otherwise similar minerals. Tourmaline is almost invariably corrugated lengthwise on its facets, and breaks transversely, with a resin-like, uneven, granular fracture, which is frequently speckled with different shades of color, as seen through a lens.

The Saxon pale yellow topazes are not rendered electric by heat, and some other Brazilian topazes are changed to red when placed in the fire.

Topaz is composed of alumina 58.38, silica 34.01, fluoric acid 7.79, from an analysis by Berzelius.

TURQUOIS—Is a beautiful stone, that varies in color from apple green to sky blue; it is somewhat similar to malachite in mode of occurrence, texture, fracture, and general appearance, and to silicate of copper for greater infusibility and insolubility. It may be easily known from the former by being more gritty between the teeth, and from the latter by changing to brown when enclosed and strongly heated in the reducing flame for a few minutes, as the silicate would become white.

It loses its color in hydro-chloric acid (muriatic), but does not effervesce like malachite, nor is it near so heavy or so soft, its gravity being from 2.6 to 3 (malachite being 3.5 to 4.5), and its hardness from 5 to 6 (malachite being from 3.5 to 4).

The residue from acid, after being well washed with water, gives the alumina reaction with nitrate of cobalt. (See Alumina.) Silicate of copper merely becomes white.

Turquois also gives much constitutional water when heated to low redness in a thin glass tube over a clean flame, which, with its coloring element, copper, that can be detected by hydro-chloric acid and blow-pipe's flame, serves to separate it from other preceding jems.

It is composed of alumina 44.5, phosphoric acid 30.9, oxide of copper 3.75, oxide of iron 1.8, water 19 = 99.95.

ZIRCON (SILICATE OF ZIRCONIA).—This stone crystallizes as

a flat octahedron, with its angles variously replaced. Thus, and in the resin-like shades of color, which streaks white, it closely resembles the oxide of tin, as well as the diamond.

Composition, zirconia 67.16, silica 33.48.

It is not of great value as a gem; but it is necessary to be enabled to distinguish it, more particularly from the diamond. When heated in a close vessel, with lime, they become pale yellow, and are then often used as diamonds.

Its specific gravity is from 4.5 to 4.7. Hardness 7.5. Like the diamond, it is partially infusible before the blow-pipe, merely losing color; but, *unlike the diamond, it may be fused with borax* to a transparent glass, and strong hydro-chloric acid etches a mark on its surface. Tin oxide yields a yellowish white oxide on charcoal, which is deposited close around the sample, and is reduced to metal by cyanide of potassium, and, being much heavier, is readily distinguished by *comparative* water treatment. Its specific gravity is also *greater than the diamond and all other gems* (the diamond being but 3.55).

The first examination, for approach to the true stone, may be for specific gravity, which at least will render many trials unnecessary, by telling you what the gem cannot be.

QUARTZ

May be distinguished from all other *vein stones* by its insolubility in all acids, except hydro-fluoric; by its hexangular crystallization; by freely scratching glass; infusibility and unchangeableness on charcoal, without flux; and by its prompt fusibility with carbonate of soda. (See chapters on Discrimination of Vein-stones for further illustration.)

Although it is generally white, it has many shades of color, and enters into various flinty combinations.

It pulverizes more harshly and slowly under the pestle than any other matrix vein-stone, particularly displayed by comparison, after having been roasted.

SILVER.

The globule, when placed on a clean bone ash cupel, before the blow-pipe's blue flame, for a few seconds, should

show no oxide from base metals, on the white ash. A button, that has been entirely freed from the base metals, will, during the period of cooling, exudate warty protuberances, that indicate pure silver; these may be lessened by slower refrigeration. It deposits a red oxide, in time.

The frosty white silver globule flattens much harder than lead, but also with perfect edge to a thin disk. Rapidly dissolved in boiling nitric acid, without residue. The silver is again precipitated by hydro-chloric acid, and by common salt, which changes it to a milky liquid, or precipitates as a white chloride, as less or more silver is present.

These chlorides are insoluble in acids, in common with lead and mercury; but the chloride of silver being completely soluble in ammonia, whilst mercury is blackened only, and lead is unchanged, it is used as a means for discriminating each when in solution. (See sulphur and soda tests.) There are other tests, but these are reliable.

Bright silver tarnishes to brownish yellow when placed into the yolk of an egg and boiled, from its affinity for the sulphur.

SOAPSTONE (STEATITE)

Is of similar chemical composition to talc (silicate of magnesia), but is more compact and slate-like in texture. It is generally nearly white, more or less colored by green or bluish green. When first excavated, it feels very soapy; but, on being exposed to a strong heat, it becomes less unctuous.

It is a good fire-stone, and, as it is easily wrought into shape, it becomes serviceable for smelting purposes.

It gives the magnesian reaction with cobalt solution, when carefully conducted. Differs from chlorite by being of lighter shade of green, and after they are first powdered, and dried over boiling water, by yielding no constitutional water, when heated in a glass tube over alcohol lamp, at a high temperature; chlorite coating the cold upper part of the interior of tube with globules of water.

SODA

Is generally found as carbonate or chloride, which are both soluble in water, giving alkaline reactions, known by their

peculiar tastes, and by coloring the flame strongly yellow; the carbonate effervesces, even in weak acids, such as are generally found about, as acetic (vinegar), citric, tartaric, etc. The manganese bead therewith, of greenish blue, is a mutual test for both.

It may be also proven by you in the iron spoon test for sulphur, by mixing it with a known sulphuret, or with the end of a sulphur match, pulverized therewith, kneaded into a paste, fused on coal, or in the spoon, and placed on a moistened silver coin; this brownish black stain being, of course, a test for both. The common salt, after having given the yellow flame, may be tested in the manners described for chlorine, or by nitrate of silver solution. (See Silver.) Also, when in crystals, by decrepitation.

SULPHUR.

The most easy test for sulphur is by roasting, and smelling the sulphurous fumes evolved during either of the methods described in the chapters on discrimination.

The best test is that of forming a soluble sulphate, by fusing with carbonate of soda on charcoal, before blow-pipe's flame, or in an iron plate, or iron spoon, in open fire, and placing it on a moistened silver coin. The smallest quantity thus treated, by staining the coin from light brown to brown black, reveals its presence.

This is facilitated by first dipping the silver coin in boiling water, or warming it over a hot iron or a clear flame from a lamp, as this slight additional temperature greatly increases the affinity of sulphur for silver. (See chapters on discrimination by blow-pipe, and by more ordinary facilities in the new methods for practical men.)

TALC (SILICATE OF MAGNESIA)

Is a soapy mineral, that varies in color from white through the shades of green, showing an unusual pearly lustre. Unlike mica, in being non-elastic. Its laminæ are, however, flexible, and so soft that they may be scratched by the nail.

It frequently occurs in a divergent, foliated, specimen form; but its valuable properties for the miner are more par-

ticularly displayed by its general dissemination in the talcose slates of the gold fields. In California, it is also found more or less pure, in massive beds and dikes; the exterior faces being more or less conchoidal, of pearly smoothness, and in variegated shades, from white to green, on the same face or stone. Those, being of a mixed composition, are generally much harder.

Impalpably fine mechanically suspended talc frequently accompanies chlorite and clay on the walls of mineral veins, that traverse talcose clay slates, and is regarded as an equally favorable indication, as explained in Section I, Chapters VI, VII, and VIII.

TELLURIUM

Is of tin-white color, and is sometimes found in natural metallic condition. It burns green, and almost entirely volatilizes as a dense white vapor, before the blow-pipe's blue flame, which deposits its yellowish white oxide on charcoal; this oxide, being re-heated where it lies, before the blue flame from blow-pipe, again passes away with a peculiar green flame. These volatilizations of metal and ores can only be effected at a high temperature, as compared with metallic and mineral antimony, arsenic, sulphur, and bismuth.

Its ores are those of graphic tellurium, yellow tellurium, and black tellurium.

The first of which, from an analysis by Klaproth, yielded, of tellurium 60, gold 30, and silver 10. It has been found in small quantities in the quartz veins at Offenbanya and Nagyag, Transylvania; and in much more profitable quantity at Carson Hill, Calaveras County, California, where it occurs in the veins of the New Melones Gold and Silver Mining Company. This Californian ore of tellurium is mostly graphic, but sometimes black tellurium is intermingled. It is of a more or less tarnished steel-gray color. Its specific gravity is about 5.7, and it ranges in hardness from 1.5 to 2.

The second (yellow tellurium), from an analysis of the same authority, is composed of tellurium 44.75, gold 26.75, lead 19.50, silver 8.50, and sulphur .5; the latter being accidental, it stands, by Berzelian formula, as telluret of gold, lead, and silver.

The third (black tellurium), from four examinations made by Klaproth, Brandes, Berthier, and G. Rose (where the two first only approach to similarity of analysis), the quantity of tellurium varies from 13 to 38.37, the lead from 60 to 85 per cent., the gold from 0 to 6, the silver from 0 to 1.28, copper from 0 to 1.3, antimony from 0 to 4.5, and sulphur from 0 to 11.7. Such differences but serve to show that the samples were either not well selected, or were of unsettled constitutional forms, and that most of the other minerals merely happened to be present. The last analysis, of G. Rose, gave 38.37 of tellurium, 60.85 of lead, and a probably chance quantity of 1.28 silver; thus placing it as a bi-telluret of lead. Therefore, its specific gravity is in this pure state 8.16, and its color tin-white; but, as may be supposed, its specific gravity varies down to 7, and its color to very dark lead gray and iron black, as black tellurium and the other minerals are more or less present. Its hardness varies from 1 to 1.5.

These ores are valuable for the precious metals they contain, and may be best recognized by—

1. Their dense white fumes at high temperature, the green color produced before the blue flame when its white, or (if lead is present) brownish yellow oxide, is re-flamed.

2. The white oxide deposited in the upper end of a close glass tube, when the mineral is subjected to a heat that almost melts the glass (being much higher than arsenic, bismuth, sulphur, antimony, or mercury); which, on being re-heated in this state and position, quietly fuses to colorless globules, or in minute orbicular patches. It evolves no smell, unless selerium, sulphur, or arsenic is also present.

3. Each kind may be separated by a lead assay with carbonate of soda (1 part of ore to 3 parts of the carbonate), and subsequent cupellation, which informs you whether it be a telluret of *gold aud silver, without lead*; a telluret of *gold, silver, and lead;* or the bi-telluret of *lead alone*, as well as the ratios or quantities of each metal.

Tellurium may be also detected, in all its combinations, by first fusing a finely pulverized, intimate mixture of the ore with half its volume of carbonate of soda and charcoal, at a full red heat, in a close-ended tube; and then, after it

becomes quite cold, to dissolve the telluride of sodium thus formed in a few drops of hot water, when, if the substance contained tellurium, this water will be colored from a more or less dark amethyst to purple, according to the quantity present in the ore. An old tea-cup, crucible, or clean iron spoon, may be used for this purpose, if you have no *test tube.*

TIN

Is invariably obtained from its oxide, which may be known by various fire, water, and acid tests, much better and easier than by any of its physical characters.

First concentrate in a porcelain dish, cup, saucer, plate, or basin, or on a Cornish vanning shovel, in a horn, prospector's pan, or Mexican battea, and notice its head position, and peculiar resistance to the water's sway; its color when pulverized, which varies from almost white to dark brown, through all the shades of resin; and its remarkable roughness under the finger. If quartz and some other mineral, of about 5 or 6 specific gravity, and of different appearance, are not present, it may be well to add them, for the sake of comparing the superior specific gravity of the tin oxide.

Knowing by this means that a mineral is present that thus far resembles tin ore, next roast at a low red heat, in an iron spoon, ladle, scorifier, or crucible, for a half-hour, stirring, the while, with a small wire. After it becomes cold, pulverize to an impalpable powder, and re-wash until the water ceases to pass off red (caused by oxide of iron, which bruises away in water), and the residue looks resinous and entirely free from other matter.

Unless the rare tungstate of iron is present—which must be dissolved in hydro-chloric acid—this residue is tin oxide. Tin may be distinguished and separated from all the irons by being insoluble in aqua regia; the iron, being soluble, passing away in the liquor. Garnet and spinel, powdered as well as in the stone, apart from crystallization, and the "precious stone, zircon," which also crystallizes in similar form, closely resemble tin stone; but these would have passed away in the water, over the margin with the quartz; therefore, a resin-like stone, that is unaffected by red heat,

the pestle, water, and acids, is the oxide of tin; which may be still further proven by nitrate of cobalt solution, producing a bluish green on charcoal; zinc, being thus treated, showing green; but this ore would not be now present.

Metallic tin is heard to crackle, when bent in close proximity to the ear. (See Zinc.)

ZINC.

The oxide produced by the oxidizing flame, when a sample is heated on charcoal, is yellow when hot, and white when cold. If a stone of zinc ore is calcined in an open fire, the copious white fumes that arise will coat cold substances white, which oxide, on being warmed, becomes yellow.

The oxide of zinc produced on charcoal, when moistened with nitrate of cobalt, and re-flamed, readily forms perfectly green and more extensive patches than the tin oxide, which is bluish green, harder to obtain, more capricious in shape, and less generally disseminated; the oxide of tin being white both when hot and cold, and forming close to, and sometimes over, the assay piece.

Zinc is more difficult to reduce to metal than tin ores. It has a heavy, non-lustrous hue, and, unless rolled into a thin sheet, is very brittle. It is dissolved by hydro-chloric acid, with such furious haste that hydrogen gas is disengaged so rapidly that the bubbles overflow the test tube, being very different to the sluggish action of tin, whose oxide with cobalt solution is somewhat similar. Its ores will not resist water, pestle, fire, or acids, as those of tin.*

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* It will be seen from this chapter that both specific gravity and hardness become most subservient directors for the recognition of minerals, when they are in states of purity (as many are); but, when they are not so, they must not be employed.

You will, after a little practice, become more and more attached to the ever convenient and costless mode for comparison of specific gravities by water treatment.

CHAPTER VII.

ASSAYING AND REFINING OF GOLD AND SILVER.

The assaying, refining, and parting of gold and silver are the most important of all metallurgical operations; for they are not only most valuable metals in themselves, but they are universally used as representative mediums for obtaining possession, by exchange, of everything of utility or value.

Minute but profitable quantities of either, or both, may be equally disseminated or scattered throughout rock, so as to lie in perfect concealment, from even the experienced observer; whilst the more ordinary explorer for fortune may stride and pass over, in a state of most deplorable unconsciousness, immense riches, that lie immediately under his feet, to more distant regions of hopeless poverty.

Therefore, considerably more space has been devoted to these precious metal subjects than for those of the more readily known and palpable base minerals; so as to supply, under all circumstances, some ready means, from the many given, for ascertaining both their presence and value.

1. *Of Gold and Silver, fluxed with the harmless excesses of iron, litharge, and carbonate of soda; some litharge being simultaneously reduced to suitable button of lead, by charcoal.*
2. *Cupellation of lead button to obtain Gold and Silver.*
3. *To calculate the value per ton.*
4. *New method for dispensing with calculation for dollars and ounces per ton.*
5. *Preliminary roasting of suitable quantities for crucible or machine, for subsequent fusion with safe fluxes.*

6. *Separate first oxidation of the base minerals by fusion with nitre, and prompt secondary reduction by the fusing and reducing fluxes of litharge, carbonate of soda, and charcoal.*
7. *Water analysis, and direct fusion by appropriate quantities of nitre, and other suitable fluxes.*
8. *Double smelting method. Random preliminary fire assay for size of lead button, so that it may be properly fluxed in the real assay, to obtain a button of suitable size for cupellation.*
9. *Assaying of Gold and Silver by scorification. Assaying furnace. Hints for simplifying operations during smelting, scorifying, and cupelling, by an alphabetical and numerical cabinet. Fluxing and smelting.*
10. *A, B, and C. Assaying of sulphuret and free Gold by preliminary water concentration, finished by roasting, crucible, scorifier, and machine, so as to ascertain how much can be obtained by chlorination.*
11. *A, B, and C. Assaying by preliminary water concentration, and finished by mercury, crucible, scorifier, or machine, to know what can be obtained by amalgamation.*
12. *Assaying free Gold in quartz, by water, and ordinary tools. Also, smelted into button by machine.*
13. *Gold and Silver assays by common blow-pipe.*
14. *Management of scales, and weighing small buttons of Gold and Silver.*
15. *The assaying of Silver by the explorer's "Wee Pet" machine.*
16. *The assaying of Gold by machine, in its own independent way, after water concentration, by fluxed fusion; reading the dollars per ton at sight, for Gold, by the same figures that are on the Silver table, as under* 15.
17. *Assaying of Gold sulphurets by roasting, acids, water, and machine.*
18. *Assaying of Silver by roasting, acid, salt, and machine.*

19. *Assaying of Silver by ammonia, acid, salt, and machine, without roasting.*

20. *Humid assay of Silver ores, of all kinds.*

21. *The assay of Silver by salt solution, called "volumetric."*

22. *Assaying of Gold by aqua regia, etc.*

23. *A, B, and C. Assaying of Gold by chlorine gas.*

24. *Parting of Gold from Silver and the base metals.*

25. *Extraction of the Silver from a fluid alloy of Gold and Silver, by chlorine gas.*

26. *Parting of Gold and Silver, when amalgamated with mercury.*

27. *Refining of Gold and Silver from all sources.*

It requires an especial education, as well as long and varied practice, to become a thoroughly good commercial assayer; for, by fluxing improperly with the more potent chemicals, for want of full knowledge of the minerals' constituents; or by excess of heat, incomplete or protracted fusion of the sample, and purification of button, for want of practical ability; the greatest errors will be continually recurring: so that not only is a complete knowledge of the minerals necessary, but the exact actions that will be created by certain proportions of such fluxes as thus so directly decompose to oxidize or to reduce the minerals to metallic states, and also the proper appearance of such a button when purified.

In treating this subject, it will be therefore necessary, so as to conform to the practical requirements of the public, and to the generally expressed purport of this book, to avoid the more difficult and uncertain direct methods, where such dangerous and treacherous fluxes are required; and to favor the more available preliminary chemistry of roasting, for such decompositions and oxidations; and the subsequent use of fluxes, which, by forming fusible slags at high temperatures, and completing the reductions of such oxides, simultaneously with the litharge, to their respective metals; they are thus collected by the reduced lead into alloys that also

contain the precious metals; which are then cupelled in the usual manner.*

ASSAY OF GOLD AND SILVER BY CRUCIBLE.

Take any sample of mineral that has been so pulverized that not less than 3600 will pass through an area of one square inch (60 to a lineal inch), which must be intimately mixed, by treating it most conscientiously, as described in Chapter I of this Section, on the systematic preparation of the sample, both before and after sifting; and, if any time has intervened, immediately before weighing; so that none of the fine or heavy particles that may have settled in the interstices, or to the bottom, shall thus cause, by irregularity, inaccurate results. In this manipulation, when absolutely correct assays are required, you should closely observe the upper side of the sieve, for flattened disks of gold, copper, or silver, and cakes of tough chloride or bromide of silver, which have not passed through; so that, if any are found, they can be collected, cupelled with lead, and weighed, by which their ratios to the weight of the whole pile, and by calculation to the sample, may be known. If moderate accuracy is sufficient, the sieve may be inverted and lightly struck with some hard substance, to overcome cohesion, and detach the adhering particles, so that they may fall on the pile, and be equally mixed therewith.

After this pulverization and sifting, the resulting heap will be more or less stratified, and irregular in its quality, caused by the more friable and fine pieces passing through first, which are often richer than the resisting quartzose gangue. It is a complete fallacy to suppose (as many do) that the sieve is in itself an equalizer; for the very reverse is thus shown to be the case, by the variously colored stratifications on the sifted heap, and therefore it is imperatively necessary for perfect homogeneity that it should be again mixed as before by repeated collections to the centre, and trailings of

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* The materials that are required in this Assaying and Discrimination section may be obtained, when ordered by the names given, from Messrs. John Taylor & Co., whose card appears on the last leaf of the reliable firms, at the end of the book; all of whom concern the miner and metallurgist.

watch-spring shaped, furrowed paths, with the finger, from the centre outwards, before the sample is taken for the assay.

1. THE MOST REFRACTORY SAMPLE OF GOLD OR SILVER MAY BE SMELTED, STRAIGHT THROUGH, IN CRUCIBLE, BY ONE OPERATION, IN THE FOLLOWING MANNER.

Select a good crucible, of about six inches in height, and three inches internal diameter. Weigh 200 grains of this sample, taken from many places around and throughout the prepared heap, which dry in a porcelain basin, by placing it as a lid over a coffee-pot, or kettle of boiling water, if no other means are at hand, to ascertain its loss of "water-weight," by re-weighing; when necessary to do so for the American or English markets, according to their different practices.

Place this weighed sample of 200 grains in a clean, dry saucer, and add thereto 4000 grains of litharge, 400 grains of carbonate of soda, and about 20 grains of finely pulverized charcoal. Mix most intimately in the manner described; transfer it to the crucible, and vertically insert therein a four-inch iron nail, which will aid in the riddance of the sulphur by forming double sulphide slags.. Next cover with a layer of 50 grains of borax *glass* (borax previously fused at a red heat in a crucible, and poured into a clean frying-pan or mould, which reduces it to a compact glass, by expelling the water of crystallization); and, lastly, by an equal layer of common salt.

Place this crucible in a moderately strong fire; surround and support it securely by charcoal or coke (the latter makes the better fire, because it is more enduring); cover it with a large piece of either, and increase the heat of the fire as rapidly as possible; notice carefully when the crucible becomes bright red, and that its contents are in fusion, and allow fifteen minutes more to pass away; then stir the contents with a quarter-inch iron wire (that has been previously made white-hot in the fire), for about five minutes; and after closing the furnace for another five minutes, to increase fluidity, carefully withdraw the crucible from the fire, tap it gently on a flat, hard surface of iron, brick, or fire-rock, to

precipitate any scattered or floating globules of lead, for union with the larger button at the bottom, and allow it to rest thereon in a vertical position until quite cold. As this method yields a large button of lead, it had better be cupelled in the scorifier full of bone ash, as will be described.

The sample in this example was supposed to be composed almost entirely of sulphurets; but it will be advisable to concentrate by water, in a saucer, and to dry and weigh as described, to ascertain the quantity of sulphurets, etc., that are present, and flux accordingly, so as to economize fluxes. The minimum of the fluxes will be, however, for even ores that contain no sulphurets, as follows:

For 200 grains of ore,
200 grains of litharge,
100 grains of carbonate of soda,
6 grains of powdered charcoal,

covered by 50 grains of borax glass, and this by a table-spoonful of salt; the litharge, carbonate of soda, and charcoal being the variable quantities over these amounts, according to the quantity of sulphurets present.

2. CUPELLATION OF BUTTON.

Some of the suitably porous materials must be next selected, and cupels made therefrom in proper moulds, for cupelling the lead button thus obtained by the smelting, which may be either bought ready for use, or made in the following manner. Take some beef, pork, or mutton bones—the last are best—which burn in a moderately hot fire, for an hour or two, to whiteness. Pulverize in mortar, and, after sifting the whole through a fine sieve, next rid it of its soluble lime by water-washing, *without rubbing* (which would, by smoothing its raggedness, lessen its cohesive strength after it becomes dry), and pour the water into another vessel, until it has settled the impalpable insoluble powder at its bottom, when the water may be poured off, the contents of both vessels slowly dried, and the powders put into bottles, or other suitable vessels, for future use.

Cupels may be made in two ways, for present use, or as

reserved stock. The first I have made most satisfactorily by ramming moderately moistened bone ash from the first and largest bottle into an old, previously used scorifier, and indenting a concavity for the button with a tablespoon, or other better shaped tool, that happens to be around. These are easily made, and are very suitable and safe in use, where large buttons of rich metal have to be refined by cupellation; as the enclosing scorifier not only thus readily forms and retains a *large quantity* of ash, but is perfect *collateral security* for its contents. A percussion-cap box may be used in the same manner, if first *slowly dried*, as it serves for a mould; and, by the time the solder gives way, the ash will have become secure.

Those who are comfortably fixed had, however, better buy the more fragile naked cupels, or make them by especial "cupel moulds," that are sold for the purpose. In this case, the ash is made just barely wet enough to hold together, and rammed into the mould with a suitable pestle, that is best driven by some two or three blows with a wood mallet, when the ash cup that is thus formed is forced out, *during the twisting of the pestle*, slowly dried, and stored for use when required.

In both these modes of manipulation, the cupels will be enhanced in quality, if the slightly moistened pestle be withdrawn from the ash, and, after being dipped into the finer and more impalpable ash from the second bottle, it is replaced, and the surface smoothed by an accompanying judicious twist. By forming a sort of smooth surface filter for the base oxides to the more porous interior, it lessens the loss of gold and silver, and provides a better bed for minute buttons. Cupellation is thus performed, because gold and silver oxidize very slowly; whilst all the base metals rapidly oxidize by sublimation in air and absorption in molten state into the bone ash or other suitable porous support.

The cupel, or cupels, should have been dried and placed in the hot muffle during the smelting operation, so as to be in proper condition, at a *bright red heat*, for the reception of the button that has to be refined.

The perfectly cold crucible may now be broken, and its contents of slag and metal enclosed in a strong rag or several

folds of paper, and smashed with a small hammer and anvil, or between two hard stones, into numerous small fragments, and the metal extracted from the more friable debris, in one or more buttons of the alloy.

These buttons are to be thoroughly cleaned, by hammering or pliering into more solid forms; thus ridding them from the adhering flux and slag, by crippling the surface and compaction of the metal, they are easier cleaned with a brush; their specific gravity being also increased by this compression, they are also more readily fused to clean molten metal for refinement, on the hot bone ash in muffle, to gold and silver.

The button being placed on this bone ash scorifier or cupel, in the muffle, it must be watched for a minute or two, to see that it becomes molten to metallic brightness, and that it does not run over the margin. After this, a medium heat is all that is required, between the *freezing* on the bone ash of the oxide of lead (litharge) formed, and *excess* of white heat; if the bone ash is sufficiently hot to absorb the oxide in liquid condition, without leaving a surface incrustation, and the metal is molten and transfers colored spots of oxide from the centre to the circumference of the button, and the fumes are reddish brown, arising lazily to mid-height of muffle, it is at a proper degree; but if the cupel and button and the volatile oxide are quite white, and the fumes arise from the button to the very top of the muffle, it is too hot, and consequently wasteful.

At the end of this process, the heat should, however, be increased, as gold and silver melt at a much higher temperature, and their concentrated alloys at a corresponding degree; so that a superior heat is absolutely necessary to complete fluidity, for passing off its more stubborn, last remaining base metal associates.

Towards the end of the refinement, a rapid circular motion, or spinning of the last pellicle of oxides, may be often observed, which is also accompanied by a flashing play of rainbow colors immediately preceding what has been called the "brightening" of silver and gold; which is also the signal of completion, and for removal from the muffle. This so called brightening is not well expressed, for it is really a

darkening from the rainbow play of colors to that of a mirror in a shadowed position, or a water-like appearance, that the globule sometimes for a few seconds approaches more to being altogether invisible than brightly so.

On removing a pure silver button from the muffle, it exudates small warty protuberances, supposed to be caused by the escape of oxygen, which, having lost its affinity for silver from reduction of temperature, it escapes suddenly through the solid crust in this manner; sometimes one may appear, and at others several, the latter giving a peculiarly rough frosted appearance to the whole surface. These are faithful records that the button is pure silver. Silver is the whitest metal, and flattens like lead to a very thin disk, without fracturing the edges or periphery. Gold is the only yellow metal; the alloys called brass would have passed away in the litharged bone ash, or can be separated in the parting process, by acid.

When a considerable quantity of nickel, copper, or iron, is present, it will be sometimes observed that the button lacks fluidity, and cannot be oxidized to less than a certain size, where it solidifies or forms an incrustation of oxide from the refractory metal; in such cases, more lead must be added, so as to carry it away in its oxide, until it is completely ridded from the encumbrance.

3. TO CALCULATE THE VALUE OF A BUTTON THUS OBTAINED, IN TROY OUNCES, OR DOLLARS PER TON, YOU MAY REASON AND PROCEED AS FOLLOWS.

The 200 grains have been here selected as a suitable quantity, that also conforms to the American ton, for estimating gold and silver, both as regards the number of units, for more plainly explaining the basis for calculation, and to be sufficient for most gold rock, as well as for affording a large average on the silver ores. Any quantity taken for the assay has been conventionally denominated the "assay pound" by authors, for no apparently good reason; so that we will multiply this 200 by 10, and call it the assay ton (of 2000 pounds), and the weight that equals one-tenth of a grain shall be denominated the "assay pound," or one-two-thousandth, both

being avoirdupois. This pound must be always thus regarded as the unit for calculation by the decimal system, the point standing at its right, thus—1.

Now, as the 200 grains contain 2000 tenths of one grain, this one-tenth being unity, it stands in similar ratio as one pound does to the ton of 2000 pounds; so that, if the sample just assayed yielded a pure button of gold or silver of this exact weight of one-tenth grain (the space in the box for this unit should be marked), it would stand as unity, with the decimal point at its right, and would also mean that 2000 pounds, or the ton, had yielded one pound of gold or silver, and that, as *ounces* or *dollars* must be certificated, all that remains to be done is to multiply it by the number of ounces troy, or dollars that are contained in this avoirdupois pound: thus, for ounces of gold or silver; 1.x14.58=14.58 oz. per ton; and 1.x18.85=18.85 $ per ton silver; and 1.x301.367= 301.367 $ per ton of gold; which is varied continually as the results; thus, a sponge of gold from an alloy of the above weight may weigh, after it is parted from silver by acid, .01 of a grain's tenth, which, being multiplied by 301.367, will equal 3.01367, or 3 $ .01 cent gold; and, if this weight be deducted from the original button that weighed 1. it will be the correct weight of silver; and the remainder of .99 thus obtained, multiplied by 18.85, will equal 18 $ .66 cents per ton for silver. When accuracy is imperatively necessary, certain additions and reductions are sometimes made to the weight of the button thus obtained, previous to its being certificated for commercial purposes. The first has been alluded to, when disks of metal, etc., are found in the sieve, which may be thus calculated. If the weight of the whole pulverized pile, including the disks, is 1122 grains, and the disks .09 (or nine-hundredths of a grain), first, for a better explanation, multiply each by 10, so as to get them into corresponding units, or assay pounds, with the sample, and they would stand thus; 11220 tenths of a grain, and .9 (nine-tenths of a tenth grain). Now, if 11220 tenths give .9, what should be the allowance for the assay ton of (200x10) 2000 tenths? 2000, multiplied by .9=1800.0, which, divided by 11220, will give .16 to be added to the assay button obtained from a similar amount of ore that did pass through the sieve;

so that, if this assayed 1. as before, if .16 be added, it will be 1.16 for calculation.

The next allowance is for the silver in the litharge, or lead, which often contains more than should pass unchecked. One means for ascertaining this is, after thoroughly mixing your newly received litharge, to take exactly as much as you did for the above assay, and to flux and fuse in precisely the same manner as before, less the ore sample, to cupel the button, and deduct the weight thus obtained, which may be supposed to have been .01 of the unit of one-tenth grain; the former figures will therefore have to be corrected from 1. to .99, which, being multiplied by 14.58, or by 18.85, will give the correct value in ounces, or dollars per ton, for silver; and, being again multiplied by 301.367, for the dollars per ton of gold; the ounces being, of course, common to both. This explains the principle, and in practice it will be better to take tests of the silver in litharge, and in lead, for all the quantities as used in the crucible and scorifier assays, to calculate the dollars and cents instead of weight reductions for each, and book them for reference as required for subtraction.

If the large English ton of 2240 pounds is required, by taking a corresponding assay ton of 2240 tenths of a grain, the same multipliers may be retained. Suitable multipliers may be also directly used for any other quantities that are taken for the assay, from a "rule of three" stating, by multiplication and division; in this matter, divisible numbers of 2000 and 2240 had better be taken as 1000 or 1120; 500 or 560 (the latter being suitable for scorification); and either multiply the weight of the button by 2 or by 4, and then proceed as before, for a full assay ton; or multiply the aforesaid multiplying numbers by 2 or by 4 for directly constant multipliers for buttons obtained from these respective quantities.

4. CALCULATION MAY BE ENTIRELY DISPENSED WITH, BOTH FOR OUNCES AND DOLLARS PER TON:

By substituting the ounces (29160) and dollars (37710) contained in a ton, instead of the "assay ton;" thus, if it be

desired to have the result per 2000 pounds in ounces or dollars, decimate the two right-hand figures thus: 291.60 grains for "assay ton," or 377.10 grains, and make two weights for the assay ton, the first marked ounces per ton, the second dollars per ton, so as to save any further recurring attention. To have the result in ounces, take the weight marked ounces per ton, weigh, flux in proper ratio, smelt by crucible, cupel, and weigh the resulting button; taking the smallest white weight of the Oertling's set of weights, which is the one-hundredth of 1 grain, as an unit; when the weight is placed on paper, it will record at sight the number of ounces of silver or of gold in a ton of 2000 pounds, or of 29160 ounces. By dividing the beam into tenths and hundredths, the hundredths of an ounce will be read by having a *white thread* rider, of the representative weight of one ounce, or the said one-hundredth of one grain. The pennyweights and grains may be read with equal facility by dividing the lever, at the *other end*, into twenty parts for pennyweights, and these again into twenty-fourths for grains, by using the same thread rider. The dollars of silver may be ascertained with even greater facility by using the appropriately marked assay ton weight of 377.10 grains, and, the same unit or dollar weight being used as a rider, the cents are immediately read on the end of the lever marked in one-hundredths.

The box that contains the weights may be marked units, tens, hundreds, thousands, just opposite where they lie in their recesses; so that, by taking and calling the largest weight or weights from the pan, it will sound exactly as it is; thus, 162.36 grains, when taken from the pan, would be sixteen thousand two hundred and thirty-six ounces (or dollars by *its* weight) per ton; and again, if .0124 grains, when the rider is also used, was the weight, it would sound one ounce and twenty-four hundredths of an ounce (or one dollar and twenty-four cents by its assay ton), which, being read at the other end of the lever, would be one ounce, four pennyweights, and nineteen grains.

If gold is required in dollars, either use 15.9873 times (16 times is very near) as much for the assay ton as the dollar weight, or multiply this value by these figures (or by 16) for its value in dollars per ton of gold. These quantities of

ore, though suitable for crucible, cannot be passed through the scorifier, and it happens that a tenth of this quantity is just safely within its maximum powers, said to be 50 grains; but which, being governed by the natures of the ores, it varies considerably, and therefore this 37.7 grains may be considered to be the safer and better quantity.

To render this practical with the balance, the tenth of the former unit must be taken as unity, which is one-tenth the weight of the rider, or, when the rider is placed to balance on one-tenth from the fulcrum, it represents one ounce, or one dollar, and so on from 1, 2, 3, 4, 5, 6, 7, 8, 9, until it reaches the tenth mark, over pan, which, of course, is 10 ounces, or dollars (and the same as the former unit when 377. grains were taken), the cents, dwts. and grs. being now read between these marks.

5. ANOTHER SAFE AND EASY METHOD IS TO DECOMPOSE AND OXIDIZE THE BASE MINERALS BY PRELIMINARY ROASTING, AND THEN TO FINISH BY USING ORDINARY QUANTITIES OF THE FLUXES THAT FORM FUSIBLE SLAGS, AND FLUID ALLOYS, FOR CUPELLATION.

Weigh 200 grains of the ore that is known to contain sulphurets, arseniurets, etc., which mix intimately with 50 grains of charcoal powder, or common black lead powder, or graphite, and roast in a crucible in an open fire, at a red heat, for at least a half-hour, stirring it with an iron wire during the whole time. Remove it from the fire, and, if no fumes arise that can be recognized by smell, this process may be considered to have been well performed; but, if they still can be detected, the sample must be pulverized, in the same vessel, by grinding, re-mixed with a similar quantity of charcoal, etc., and be again roasted, until no such fumes pass away.

To this roasted ore (which weighed 200 grains before roasting), add 400 grains of litharge, 100 grains of carbonate of soda, and exactly 6 grains of charcoal (to reduce by this amount of charcoal a proper weight of lead from the litharge for cupellation). Mix intimately, cover with 50 grains of borax glass, this again by a tablespoonful of common salt, smelt, cupel, and calculate as before.

6. IT MAY BE PERFORMED BY SMELTING, DIVIDED INTO TWO OPERATIONS, AS FOLLOWS:

The first being the oxidation of the base minerals by nitre; the second by charging thereon, after the strength of nitre has been first thus neutralized and volatilized, a mixture of litharge, charcoal powder, and carbonate of soda, to more promptly collect the gold and silver by the shower of molten lead, thus reduced and precipitated, to a suitably sized button, for cupellation.

The advantages of this method are:

1. That it extracts as much of the precious metals as any other crucible mode.

2. That it may be performed with much less knowledge of the chemistry of fire and fluxes, without risk of insufficiently correct results.

3. The nitre being first and separately used, in sufficient quantity for the worst ores, thoroughly oxidizes the base minerals that are present, without interfering with the proper size of the lead button (sometimes buttonless) that would have to be simultaneously produced of proper size, by the *ordinary* methods of nitre fluxing.

4. It does not oxidize the precious metals.

5. The button of lead for cupellation may be thus prompty and correctly reduced from the *subsequent* (instead of simultaneous) addition of litharge, carbonate of soda, and charcoal, to the desired size for the greatest extraction of gold and silver by cupellation.

6. It requires no distinctly separate crucibles, nor *doubly fluxed and smelted "preliminary"* and *real* assays, but may be performed by the same fusion, in the following manner.

Take (the worst of all examples) a sample of finely pulverized, very closely concentrated, *unroasted* sulphuret of iron, that contains but little gold, and weigh out 200 grains, in the careful manner described for previous assays. Now, to completely oxidize the sulphuret of iron by fusion with nitre, it will require about 2½ parts of the latter to 1 part of the former; so that we must now add 500 grains of nitre, and thoroughly mix it in a crucible with the 200 grains of ore, which should occupy but about one-quarter the capacity of

the crucible, as this flux, being somewhat violent in action, would otherwise, by projecting some of the contents, cause loss. Place the crucible into a moderately hot fire, and after the sample is smelted into a state of complete fusion, which will occupy about fifteen minutes, stir it with a hot iron wire for two minutes; then add quickly, with a long-handled scoop, an *intimate mixture* of 200 grains of litharge, 200 grains of carbonate of soda, and 6 grains of finely pulverized charcoal, that had been previously prepared and scooped for more immediate charging. Smelt at full heat for five minutes, withdraw from the fire, tap the crucible to settle the lead, and, after it is quite cold, break it and manipulate the button, cupel, and calculate, as previously directed. If the operation has been well performed, this button should weigh from 150 to 180 grains.

7. WATER EXAMINATION, AND DIRECT FUSION WITH NITRE, ETC.

Concentrate 200 grains by water, dry the heavy residual in a basin or plate, over a coffee-pot of boiling water, and carefully examine for the different sulphuret minerals, which separate into heaps, and weigh for correct and direct fluxing by nitre, litharge, carbonate of soda, charcoal, borax, and salt, assisted by the following table and geometrical device.

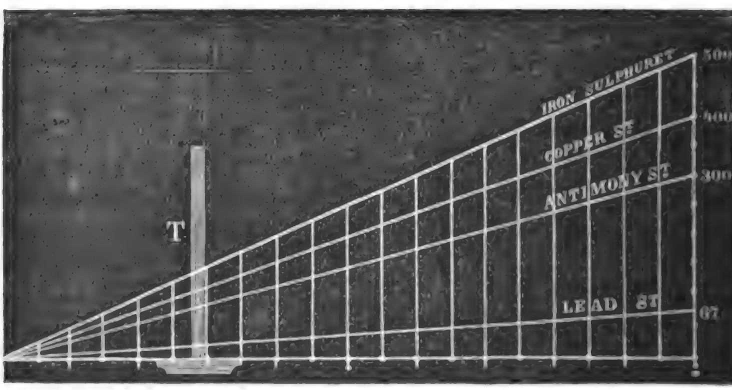
To oxidize 200 grains of sulphuret of iron, it requires about 500 grains of nitre.
To oxidize 200 grains of sulphuret of copper, it requires about 400 grains of nitre.
To oxidize 200 grains of sulphuret of antimony, it requires about 300 grains of nitre.
To oxidize 200 grains of sulphuret of lead, it requires about 67 grains of nitre.

Now, having ascertained by water concentration how much of either of these sulphurets are contained in your sample of 200 grains, you can weigh another sample of 200 grains, and add thereto the exact amount of nitre required, which may be ascertained in the following manner. If say 20 grains of the sulphuret of iron were obtained, it would require but just one-tenth as much nitre as it did when the whole 200 grains of sulphurets were present. Or, by "rule of three,"

if 200 grains of sulphuret of iron ore required 500 grains of nitre for its oxidation, how much nitre would 20 grains of sulphuret of iron require; or $\frac{500 \times 20}{200} = 50$ grains of nitre.

To save the time of calculation, where many assays are made, it may be readily effected upon Cut 19, either for these or for any other ratios, as follows. Lay out on a suitable board a base line, which divide, from left to right, into 200 equal parts (to represent the grains of assay); erect (by a square) at the extreme right, on the two-hundredth mark, a perpendicular line, which mark off, commencing from the bottom, into equal units, until the maximum number and height of 500 is attained (the greatest quantity of nitre required), and mark every tenth division of the base and

Cut 19.



perpendicular lines with their proper figures. Next draw *four* diagonal lines from left to right, the *first* commencing at the zero of base (or left end of the 200 line), and ending at the 500, or top of perpendicular; the *second*, from this zero to the 400 of perpendicular; the *third*, from zero to 300; and the *fourth*, from zero to the 67 grains of nitre required for oxidation of 200 grains of sulphuret of lead, and it is complete for immediate reference, for ascertaining how much nitre is required for the oxidation of any fractional number below 200 grains of either of these sulphurets. Any number of other diagonal lines may be also drawn on the same board or paper, and suitably marked for the particular sulphuret, or purpose, for which the *ratio* of this or any other flux is

required. The base line may be also divided in hundredths when preferable; or into *both at the same time*, by *darkening* the *alternate* marks, and figuring both *over* and *under* the line; the first showing one-hundredths, the second two-hundredths.

All that is necessary to be done for using the instrument is to apply a square to the board, so that its perpendicular edge shall stand over the figure on the base line, that represents the weight of the concentrated sulphurets, say about 60 grains; then, with an open compass to gauge the perpendicular distance from the base line to where the square's edge crosses the diagonal line that is marked for the particular sulphuret required; next transfer the compass points to the graduated vertical line; the one point being placed on the intersection of base and perpendicular, the other will point, on the vertical scale, to the exact quantity of nitre required to oxidize the sulphuret metal present.

If two sulphurets are found together, they must be measured separately, and the sum (required for each) taken.

The base line may be also divided into 50 equal parts, for the number of grains used in scorification, and the perpendicular into suitable unequal parts, commencing from 6 parts of lead at the base (the least quantity of lead taken for the 50 grain assay), when iron, copper, or nickel, are absent, and so graduated that the proper number of necessary additional parts of lead may be measured by the compass, when transferred from the perpendicular height over the fractional concentrated quantity to the end scale, for the proper fusion of such refractory minerals when they are present.

These calculations may be indefinitely modified by using different vertical and horizontal scales; and may also be performed by a single angle of diverging lines, if separate scales, of the extreme vertical length, be individually divided to the number of parts required to oxidize the 200 or 100 grains of sulphurets. Thus, if the first vertical, smallest angle measurement of the 67 were divided into 500, it would serve also for the fractional ratios of that number, when measured by its parallel and vertical line from the base, as it now does by the largest angle, when the reduced distance of the compass points are replaced thereon, to ascertain the number of grains required, and denoted on its scale, under

the upper point. An ordinary oblong table may be used for this purpose, by simply laying out the base line of 50 inches in length, divided into 200 quarter-inch parts; and erecting the perpendicular 31¼ inches high, of 500 sixteenth of an inch parts. Or a piece of plank may be used, of half this width, divided into 500 thirty-second inch parts.

This exact quantity of nitre being ascertained, must now be added to the 200 grain assay, with about 400 grains of litharge, 200 grains of carbonate of soda, and, if *no lead is present*, exactly 6 grains of finely pulverized charcoal; but, if any lead ore is found, every 40 grains of ore must abstract 1 grain of charcoal. Mix very intimately, and transfer it to a crucible that would hold at least thrice this quantity; and, after covering it first with about 50 grains of borax glass, and lastly with a tablespoonful of salt, it may be smelted, cupelled, and calculated in the manner described under No. 1.

8. DOUBLE SMELTING METHOD. RANDOM PRELIMINARY FIRE ASSAY, FOR SIZE OF LEAD BUTTON, SO THAT IT MAY BE PROPERLY FLUXED IN THE SECOND AND REAL ASSAY, TO OBTAIN A BUTTON OF SUITABLE SIZE FOR CUPELLATION.

This mode of assay has been recommended and fully described by John Mitchell, in his large Manual on Practical Assaying; and as he has, in these paragraphs, fully exposed the doubtful action of fluxes, and also given the means used for testing the reducing and oxidizing powers of argol and nitrate of potash, and for assaying of litharge for silver—all of which, as well as the test lead (which is known by cupellation) must invariably be examined and allowed for by you, if accuracy is required—I have quoted his instructions, as follows.

"SPECIAL DIRECTIONS FOR THE CRUCIBLE ASSAY OF ORES AND SUBSTANCES OF THE FIRST CLASS.

"The ores and substances belonging to this class may, for the convenience of assay, be further subdivided on the following principle. It has already been seen that sulphur, and other substances having a great affinity for oxygen, reduce metallic lead from litharge in proportion to the amount of reducing matter present; and, as it is necessary in this kind of assay that no more than a certain quantity of lead alloy should be submitted to cupellation, some kind of control must be exercised by the assayer, to keep the quantity of lead reduced in due and proper bounds. This is readily accomplished by what the author calls a 'preliminary assay,' by which all ores and substances of this

class are divided into three sections: Firstly, ores which, on fusion with excess of litharge, give no metallic lead, or less than their own weight; secondly, those which give their own weight, or nearly their own weight, of metallic lead; thirdly, those which give more than their own weight of metallic lead. The preliminary or classification assay is thus conducted:

"Carefully mix 20 grains of the finely pulverized ore (all siver ores must be passed through a sieve with 80 meshes to the linear inch) with 500 grains of litharge; place the mixture in a crucible which it only half fills; set the crucible, after careful warming, in a perfectly bright fire, and get up the heat as rapidly as possible, so as to finish the operation in a short time, to prevent the action of the reducing gases of the furnace on the oxide of lead, because, if a great length of time were taken in the operation, a portion of the lead reduced might be traceable to the furnace gases, and the result of the experiment vitiated. After the contents of the crucible are fully fused, and the surface perfectly smooth, the crucible may be removed and allowed to cool, and, when cold, broken. One of three circumstances may now present itself to the assayer: Firstly, no lead, or less than 20 grains, have been reduced; secondly, 20 or nearly 20 grains, more or less, may be reduced; and, thirdly, more than 20 grains may have been reduced.

"Now, as it has been already stated, 200 grains of lead alloy is a suitable amount to cupel; and, as 200 grains is the best quantity of ore to submit to assay, it will be evident that ores and substances of the second section, or those bodies which give their own weight, or nearly their own weight, of lead alloy, simply require fusion with a suitable quantity of litharge and an appropriate flux. Ores of the first section require the addition of a reducing agent, in quantity equivalent to the standard amount of lead alloy (200 grains); and ores of the third section require an equivalent quantity of an oxidizing agent, or an amount of some body which will oxidize the lead in excess of 200 grains of alloy.

"The reducing agent employed is argol; the oxidizing agent, nitrate of potash. It is necessary, before commencing an assay of a silver ore, to determine how much lead a given weight of the argol the assayer has in use will reduce, as also how much lead a given weight of nitrate of potash will oxidize. These assays are thus made:

"*Assay of Reducing Power of Argol.*—Carefully mix 20 grains of the argol to be tested with 500 grains of litharge and 200 grains of carbonate of soda; place the mixture in a suitable crucible, and cover with 200 grains of common salt. (It is best to mix two such quantities, and take the mean of the results.) Fuse with the precautions pointed out in assay of substances of the first class, containing lead. Weigh the resulting buttons, and take a note of the mean weight, which will represent the amount of lead reducible by 20 grains of argol.

"*Assay of Oxidizing Power of Nitrate of Potash.*—Mix 20 grains of finely powdered nitrate of potash, 50 grains of argol, 500 grains of litharge, and 200 grains of carbonate of soda; cover with 200 grains of common salt, and fuse as above. Weigh the resulting button. Now calculate the amount of lead which should have been reduced by 50 grains of argol, and the difference between that and the amount of lead reduced in this experiment will represent the amount of lead oxidized by 20 grains of nitrate of potash. 30 to 32 grains of ordinary red argol reduce about 200 grains of lead; and 23 grains of pure nitrate of potash oxidize about 100 grains of lead. The assayer must, however, adopt the numbers found by himself by experiment, as some samples of argol and nitre are more or less impure. He must also examine every fresh supply of litharge for the amount of silver it contains, in the following manner:

"*Assay of Litharge for Silver.*—Mix 1000 grains of litharge with 30 grains (or any other quantity that may be, by experiment, found requisite) of argol, 200 grains of carbonate of soda, and cover with salt, as already directed. Fuse the mixture in a suitable crucible; allow it to cool; break and cupel the button obtained, as hereafter to be described; take a note of the amount of silver obtained; and, as 1000 grains of litharge is the standard quantity for a silver assay, the amount of silver, indicated as above, is to be deducted from the

amount of silver obtained in the assay of any silver ore, until that quantity of litharge is consumed.

"*Assay of Ores of the First Section.*—Make a preliminary assay, as already described. Suppose 10 grains of lead result; then, as 20 have furnished 10 grains, so 200 grains of ore would furnish 100 grains of lead, or 100 grains less than the quantity best adapted for cupellation; so that, referring to the assay of argol, and finding that from 30 to 32 grains reduce 200 grains of lead, then it is clear that the reducing power of from 15 to 16 grains of argol, in addition to the reducing power of 200 grains of ore, is necessary to furnish 200 grains of lead alloy. In this case, the ingredients required in the actual assay, or 'assay proper,' would stand thus: 200 grains of ore, 200 grains of carbonate of soda, 1000 grains of litharge, 15 to 16 grains of argol. These materials are to be thoroughly well mixed, placed in a crucible which they about half fill, and covered first with 200 grains of common salt, and then 200 grains of borax, and submitted to the fire with the usual precautions; when the flux flows smoothly, the assay is complete; it may be removed and allowed to cool, the crucible broken, and the button obtained must be hammered into a cubical form, and should approximate to 200 grains, either more or less within 10 grains. Two crucibles must always be prepared. It will also be here convenient to mention that the argol and nitrate of potash are the only substances whose quantities vary in the assay of silver ores, the amount of these variations being determined by the preliminary or classification assay.

"*Assay of Ores of the Second Section.*—If the preliminary assay of the sample submitted to assay furnish from 18 to 22 grains of lead, then the assay proper may be thus made: 200 grains of the ore, 200 grains of carbonate of soda, 1000 grains of litharge; well mixed, and covered with salt and borax, as above. Fuse with due care, and reserve buttons of lead alloy for cupellation.

"*Assay of Ores of the Third Section.*—If the sample on preliminary assay furnished 40 grains of lead, then the 200 grains employed in assay proper would give 400 grains, or 200 grains of lead in excess; refer now to note-book for quantity of lead oxidized by nitre; suppose the nitre pure as just stated, 23 grains will oxidize 100; therefore, 46 grains are equivalent to 200, and the assay proper will stand thus: 200 grains of the ore, 200 grains of carbonate of soda, 1000 grains of litharge, 46 grains of nitrate of potash. The nitrate of potash to be weighed first, finely pulverized, and then well mixed with the remaining substances, and covered with salt and borax. The crucible in this assay must be larger than in the two preceding cases; the mixture should not more than one-third fill it, as there is a considerable action set up between the oxygen of the nitre, and the sulphur or arsenic, or any other substance that may be the reducing agent in the ore; for, in fact, the nitre does not directly oxidize the lead, which sulphur, etc., might have reduced, but oxidizes its equivalent quantity of sulphur, or whatever other reducing substance there may be in the ore, so as only to leave a sufficient amount to reduce 200 grains of lead, in lieu of the 400 as indicated by preliminary assay, or when the reducing power of the ore was allowed to come into full play. The buttons obtained in this case are also to be reserved for cupellation."—*John Mitchell.*

9. ASSAYING OF GOLD AND SILVER BY SCORIFICATION.

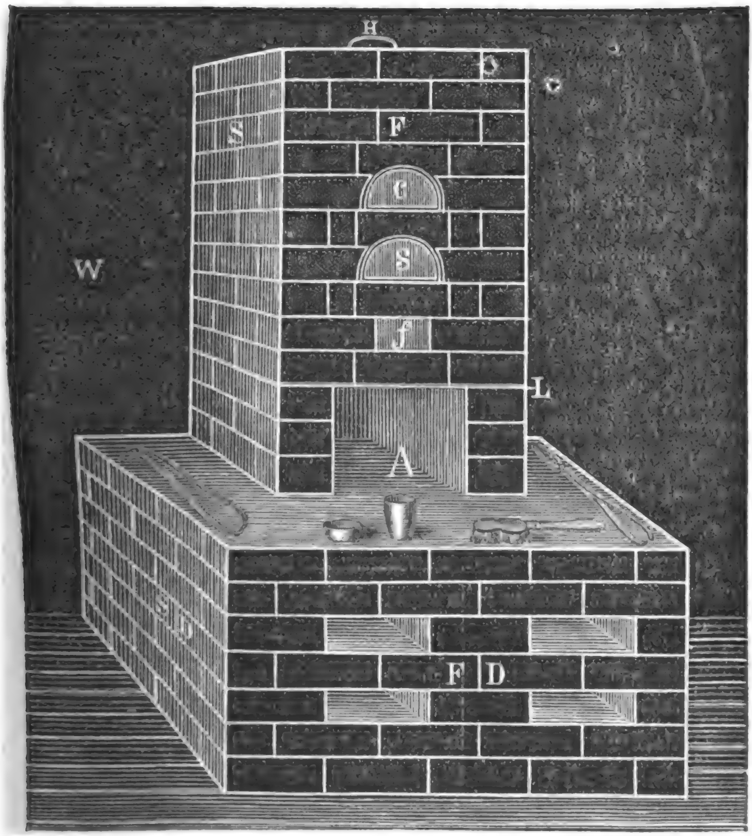
This, the cheapest, easiest, cleanest, quickest, safest, best, and most scientific method for assaying gold and silver, is performed by *shallow dishes* called scorifiers, *in a hot muffle*, which is *surrounded* by fire, instead of being *fused in a crucible, within the fire.*

It will not be out of place to give an illustration here of an assaying furnace, and the most convenient and economically suitable dimensions of its exterior shape and interior

capacity, as required for the miner. I submit the following for such a purpose, which can be made either of unbaked or baked bricks. Although, however, these will answer the purpose, it is better to have the fire part of "fire brick."

The furnace may be now built in the form shown, complete in itself, with its back abutting air-tight against the wall (W).

Cut 30.



First build the bottom dead work, marked F D (front dead work), and S D (side dead work), 4½ bricks wide in front, and 3½ bricks at the side (38 inches by 34 inches), and run this work some 7 bricks, or 20 inches high; thus forming a base for furnace, and a convenient table for resting hot crucibles, scorifiers, cupels, tongs, stirring rods, etc., as well as

being of suitable height for pouring ingots, or buttons, and for safe bottom of ash-pit, even in a wooden-floored office. Next commence to build the bottom of the ash-pit upon this dead work, by laying 2½ bricks wide against the wall, and 2 bricks to the front of furnace; that is, about 20½ inches wide by 16½ inches, somewhat in the shape of a letter ⊏ with its back to the wall; this back and the limbs are 4 inches wide; run this up, of same shape, 3 bricks high, for the ash-pit and draught-hole, and place your fire bars or grating thereon at L.

If you are likely to require the use of furnace every day, the bars had better be laid in loosely upon transverse flat sleeper-bars, that should be built in front and back, at the height of letter L, so that the fire bars may be withdrawn at the termination of each day's work. Next lay on, with as little lime as possible, one row of bricks, or 4 inches wide all round (at the back, the sides, and the front), and then again another row of bricks all round, except at the opening marked F, which is intended to feed as required to regulate the heat of muffles, and which is stopped by a brick's end, or other stopper, when not being fed. Next bridge this opening by hoop iron or bars of flat iron, a half-inch thick, covering 4 inches wide, or the whole width of front, and sufficiently long to turn down a half-inch at each end, to brace the furnace together, or another row of bricks, as drawn, if you have no iron. Now lay on, exactly over opening, F, the first (*scorifying*) muffle, S, so that, by resting a little higher on the *back wall* end, the drainage and discharge from within of any accidentally spilt lead (or other metal), will prevent its eating through the muffle. Just opposite the back end of both muffles, about one-inch holes should be forced through the wall of the house to the chimney, to afford direct communication and draught from the muffles, to ensure more speedy oxidation of the minerals and metals. Lay another course of bricks around the furnace, and build closely up to the sides at each end of the muffle, and another course of bricks around the furnace and over each end of the muffle, scooping out a little from under each arching brick, necessary.

Place the second (*cupelling*) muffle, C, in same manner and

position over the first, taking care that the communications to the two holes provided for the slight draught from muffles shall not be interfered with by communication with furnace fire. Again build around the furnace and muffle as before, and add thereover four more rows of brick, between which it will be advisable to place thin crossing braces of hoop iron. At three bricks above the top muffle, knock a hole, 6 inches wide by 2 inches deep, from the furnace into the chimney, and, after providing yourself with a conveniently movable furnace cover of iron or fire-stone, it is ready for being slowly dried, and then for use. The fire may be easily lighted in this furnace by putting some small pieces of kindling-wood into the bottom feed-hole at F, and then, after filling the furnace with charcoal through the more general feeding-hole at the top, to ignite it by a match or candle, through the opening, F.

Where a man has to pass through many assays of different minerals, this will be found a very subservient furnace. For such as require preliminary roasting, the upper and lower muffles may be both used in the gradually increasing heat of the *early* fire; in the *middle* of the day, the open fire at the top may receive four crucibles for copper or lead assays, whilst the upper and lower muffles, C and S, may each receive as many scorifiers, for gold and silver assays; or the one muffle may be used for scorifying, and the other for cupelling; or the one for mineral, and the other for bullion assays; or the upper muffle may be regulated in temperature for lead assays, whilst the under one shall be at a higher degree for gold and silver, or copper, by the German method; or *twelve* gold and silver assays may be smelted together (four by crucible in fire, four in the upper, and four in the lower muffles, by scorifier), in forty minutes, and cupelled within the hour, after the furnace is at proper heat, and that, too, by the smallest possible amount of fuel. On one occasion, having everything previously numbered, weighed, and fluxed, I passed through, in a similar furnace, thirty-two silver assays, three of lead, and one of copper, in five and a half hours, without assistance; but all *ordinary day's works* may be brought, by the use of the double muffle and crucible, within the one short turn or term of smelting and cupellation.

Where much assaying had to be accomplished, I have made a portable stand, with four rows of compartments, having ten pigeon-holes in each row, numbered from 1 to 10.

The bottom row	was	also denominated	A, from 1 to 10.
The second row	"	"	B, from 1 to 10.
The third row	"	"	C, from 1 to 10.
And the fourth row	"	"	D, from 1 to 10.

The first row, A, had square scoops, numbered from 1 to 10.
The second row, B, had scoops numbered from 1 to 10.
The third row was lined with iron from 1 to 10.
The fourth row contained small watch glasses, from 1 to 10.

Whilst, at the back, numbered parting flasks reclined, that ranged from 1 to 10; underneath which were alcohol lamps, where gas cannot be had, that contained sufficient alcohol to burn thirty minutes, the maximum boiling time required for parting of silver and gold.

Now, on receiving say eight samples that are required to be assayed for gold and silver, one for lead, and one for copper, you will first take eight scorifiers (or eight *pairs*, if duplicate check assays, for commercial exactitude, is desired), and number them with red chalk, or with a file, on the exterior, from 1 to 8, and it will be also advisable to smear them within with red chalk, to prevent adhesion during roasting, and the absorption of the litharge into the scorifier, that would hasten its fusion, and eat holes through its bottom, during the smelting process.

Next take a crucible for the lead assay, and another for the copper, and number them by notches made with a file on their rims. Place these scorifiers and crucibles opposite their respective numbers, to await the weighing, fluxing, and charging period of operation, after all the samples are pulverized and homogeneously mixed in the manner described for preparation of the sample, and placed in the several numbered boxes of row A, and appropriately marked, say as follows.

A 1—Average from the "Victoria" lode at bottom of shaft, for *silver*.

A 2—Average from 1000 foot level, north end, for *silver*.

A 3—Average from back of 1000 foot level, No. 1 stope, north, for *silver.*

A 4—Average from back of 1000 foot level, No. 3 stope, south, for *silver.*

A 5—Average from back of 900 foot level, No. 2 stope, north, for *silver.*

A 6—Average from bottom of winze, in 900 foot level, south, for *silver.*

A 7—Average of stones brought in by Company's prospector, for *gold and silver.*

A 8—Average of the tailings from last run, for *silver.*

A 9—Average from the "Abraham Lincoln" lode, for *lead.*

A 10—Average from the "Grant" lode, for *copper.*

Having these boxes thus plainly marked, you will next proceed to weigh out from each sample the proper quantity for each assay, and place them into the flat-bottomed iron scoops in row B; and, after adding the desired fluxes, mix intimately as directed, and transfer them to the correspondingly numbered scorifiers or crucibles. Now smelt into the *button,* which, when cleaned, may be placed in the same numbered scoop of B, for cupellation. Cupel, and place in row C. Part by nitric acid in the numbered parting flask at the back of frame, and place the deposit of gold from cupelled button in row D.

Thus, A 1 would receive the ore for "*Assay.*"

B 1 would receive it when weighed, and the resultant smelted "*Button.*"

C 1 would receive the "*Cupelled button.*"

D 1 would receive the "*Deposit*" of parted gold.

The initial letters of rows thus indicating the corresponding initials of the results.

HOW SCORIFICATION FOR GOLD AND SILVER IS PERFORMED.

When concentrated sulphurets of iron or copper contain gold, they should (notwithstanding what has been said in favor of scorification) be mixed with charcoal, and separately roasted and stirred, in a scorifier or crucible, with an iron wire, for at least a half-hour, in a moderately hot muffle or open fire, if it be intended to extract all the gold.

Such samples should be mixed with charcoal, in a well chalked or red-ochred scorifier; gradually roasted and stirred, at the *commencement of the day*, as the *fire is burning up;* withdrawn as soon as the muffle becomes hotter than a red heat; and then treated as ordinary ores.

For these, as well as for all other ores, 50 grains is as much as the scorifying mode will do justice with; and you may therefore take the 50 grains for this roasting ore (or the same weight for any other that does not require roasting), unless you prefer to take 37.71 grains, or 29.16, and thereby to avoid all calculation for value in dollars or in ounces, as previously described.

1. It may be fused with test lead alone, if desired. To one part of the ore add at least six parts of test lead (lead granulated and free from gold and silver); mix these intimately together, in the *same scorifier in which it was roasted*, and cover it by a layer of six parts more of lead. *All the silver ores*, and the *ordinary gold ores*, may be mixed (without roasting) with lead, and immediately scorified, by being placed in the hot muffle, according to their numbers, when, after the door is closed, the fire is urged to its greatest heat for fifteen minutes; during this time, the roasting is performed, when the lead somewhat tardily melts into numerous globules, which, falling through the mass, collect and concentrate the precious metals by fusion, thus forming union into one central bottom button of lead. In some fusible samples, the smelting is now completed; but it will be always advisable to allow the button of lead to oxidize into litharge, by the opening of door for a second fifteen minutes, which, by rendering all the gangues more fusible, greatly enhances the realization of its gold and silver, whilst at the same time it reduces the size of the button for cupellation. At the end of this thirty minutes, it will be advisable to stir the contents of each scorifier with a long eighth of an inch wire, suitably bent to an L hook (using a clean, separate wire for each), and note particularly that the molten slag does not stick to the end, as molasses would, but that it is just as fluid as the molten lead; or the assay lacks sufficient heat for the effectual extraction of the silver, and gold.

By the way, the furnace is oftener too cold than too hot;

charcoal cannot render the muffle too hot for this purpose; but coke or stone-coal may do so, and burn the bottom into holes. (See under 2, for addition of lead, etc., when cupelling.)

After the lead has oxidized sufficiently to encroach from the side of the scorifier, entirely over the molten lead, the door may be closed for ten minutes, to increase the heat, when the scorifiers must be emptied into suitably shaped and numbered conical moulds, and, when cold, they are cleaned, hammered into cubes, and respectively transferred to their numbers in row B of numerical frame.

They are next cupelled as previously described, and placed in row C; and, if suspected of containing gold, parted by acid, in the correspondingly numbered flask at the back of frame, and the deposit of gold placed in its numbered watch glass at D.

2. As litharge (the oxide formed from the lead) attacks the scorifier, half the weight of borax (or common window glass) as the ore may be used. It also renders some earths much more fusible, but, I think, interferes with the effectual initial roasting of other refractory metallic minerals, by sealing them over before oxidation is effected. As a rule, it is better to use one of them where ores are *not highly charged* with sulphurets of iron, or copper.*

In the calculation of value of button in ounces or dollars per ton, see backwards, under third and fourth heading, near the commencement of chapter; and, for parting of silver and gold, forward, under twenty-fourth, twenty-fifth, and twenty-sixth headings, near the end of this chapter.

Thus, the operator's mind being thoroughly relieved by this system of numbered notes, can devote all his attention to the appropriate manipulations that must be so closely watched, if correct results are desired.

Different men may also take on in shifts, if necessary, without confusion or injury to the work, at any stage of the operations.

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* I prefer to prepare the scorifiers by a previous fusion of a *small amount of borax* therein, to form a sort of surface glaze, as earthenware; which protects the vessel, without hindrance to oxidation, during the roasting stage.

10. ASSAYING OF SULPHURETS FOR GOLD, BY PRELIMINARY WATER CONCENTRATION, FINISHED BY CRUCIBLE, SCORIFIER, OR MACHINE, SO AS TO ASCERTAIN HOW MUCH CAN BE OBTAINED BY CHLORINATION.

This is the mode *par excellence* for the practical purpose, of what can be obtained, after milling, by chlorination. You may concentrate, as described in Chapter III, a *very large quantity*, for correct average, precisely as is done on the large scale, and thus obtain an exactly similar result, by drying and roasting the heavy residue for treatment as follows.

A. By roasting and crucible fusion, as described under No. 5, and deduct one-tenth of this *fine gold* fire assay, for what *should be obtained* by chlorination.

To dispense with calculation, you may also refer back to No. 4; or, to make it re-appear here in still plainer terms, to proceed on the following basis. As a 2000 pounds avoirdupois ton of gold contains 29166⅔ Troy ounces, it follows that, if any weight be made that contains this same number of units, each and every one of such units of weight that can be obtained from a gold sample will be the correct representations of ounces per ton of such, thus obtained, alloy of gold, silver, etc.

For crucible smelted assay of quartz that contains any amount of sulphurets, etc., you may take the *one-tenth* of a Troy grain as a suitable unit to represent one ounce (which is *ten times* the weight of the *smallest white weight*, of the very superior set of guaranteed weights manufactured by Oertling, of London). You can make a rough brass weight for yourself, by putting into one pan of your scales 29166⅔ of these units (that is, 2916 grains and 6⅔ tenths of a grain, or 6 Troy ounces, 1 pennyweight, 12⅔ grains), and filing your new weight to balance. Mark this "assay ton," for unit ounce, of the one-tenth grain (or second ten weight) of Oertling.

Thus, if the button weighed 8 of such weights, it would be 8 ounces per ton, of such and such fineness or value per ounce. If 8 and two-tenths, it would be 8 ounces and (twice two-tenths) 4 pennyweights.

The fine gold can be re-weighed, after it has been parted,

and multiplied by 20.67 for dollars per ton. (See "Parting," towards the end of chapter.)

B. For scorification of quartz that does not contain more than fifteen per cent. of the heavy sulphurets and gold, a tenth of the last quantity may be taken, and, provided a magnet or magnetized knife-blade is used to extract the metallic iron (broken from the mortar), this will generally be within what is found in quartz ledges.

In taking this weight, 291.66 grains, or 12 pennyweights and 3⅔ grains, to make a weight for a scorifying "assay ton," the one-hundredth of a grain, or the smallest white weight of the Oertling balance, stands as unity, or the "assay ounce." It may often happen that no more than one and a half per cent. of sulphurets occur in ledges; so that the larger of these "assay tons" concentrated residues (with the precautions taken for iron), may be even scorified, without requiring the concentrated sample to be further reduced by acid.

C. Take, for machine, 160 grains of quartz, that contain no more than fifteen per cent., or 1600 that contain less than one and a half, and after concentration, ridding of metallic iron, drying, and roasting as for the crucible and scorifier, flux, smelt, and cupel by machine, as directed for the assay of silver ores by the machine.

The value is then read under its calculating lever, or between its diverging metallic slips, in dollars per ton, at sight, for the 160 grain ton, and by taking off one figure (or decimating it) from the right-hand side of the underlying column, that is headed by a similar number to that on the weight, the answer to 1600 grains may be known.

11. ASSAYING BY MERCURY, CRUCIBLE, SCORIFIER, AND MACHINE, TO KNOW WHAT PROPORTION OF GOLD CAN BE OBTAINED BY AMALGAMATION.

This is again *par excellent*, and the only method that truly indicates how much gold may be obtained by battery, pan, arrastra, or barrel amalgamations; and these (No. 10 and No. 11) methods also show, when combined, how much there is really in the rock, how much can be extracted by ordinary

milling, and, by their difference, what the sulphurets are worth.

Take the largest weight named (of 6 ounces, 1 pennyweight, and 12⅔ grains) of ore; concentrate, and place the heavy residue into an iron mortar, with a cupful of water. Next add about one pound of well strained and cleaned mercury, and stir, without grinding too much (for the object is to amalgamate only the free gold), for about two hours, when you may leave it over night. Stir for a few minutes in the morning, with the mortar full of water; pour off, and carefully strain the mercury through a compact chamois or buckskin. If the rock is very poor for gold, it will be convenient to add about one grain of zinc, or fine silver, to amalgamate with the mercury, so as to obtain a more tangible body of amalgam, for straining and fire treatment.

Sublime the amalgam *in a crucible*, either in the fire, or before the machine's roasting furnace, to pass off the mercury, etc. Next flux in crucible, in scorifier, or before machine, like the silver or lead assays; cupel, and part, if necessary; and ascertain its value, as before, by the unit weight system.

In this instance, the gold being little and free, the machine equals the scorifier and crucible for quantity, and requires the assistance of their weighing machine; but it might have been performed for the *three* by the calculating lever of machine, if, instead of the "assay ton" being 29166 grains, it had been either 16000, 1600, or 160 grains, as required to conform to the principle of its calculating lever.

If the 160 had been taken, the table would have been read in dollars per ton at sight.

If 1600, the right-hand figure should have been cut off or decimated.

If 16000, two right-hand figures, etc.

12. FREE GOLD IN QUARTZ MAY BE READILY ASSAYED BY PRACTICAL MEN, WITH ORDINARY TOOLS, AS FOLLOWS.

A. Concentrate the finely pulverized "assay ton" of 6 *Troy ounces*, 1 pennyweight, and 12⅔ grains, very carefully, in the manner described in Chapter III, Section III.

If very close results are required, such as will not, however, be very probably realized on the large scale, first shake the sample in a close bottle, to thoroughly wet the ore, and settle the gold, that might otherwise float away in first water. After the iron has been extracted, before the water has been poured off, by a magnetized knife-blade or magnet, dry the solitary residue of granular gold, by placing the basin, saucer, or plate, over a coffee-pot that contains boiling water, or, in this case, over any warm surface, lamp, or fire, and transfer or sweep it into a previously balanced scale-pan, or paper, as described under No. 14, for the most exact weighing of small quantities. Each tenth of a grain thus obtained will represent one ounce per 2000 pounds' ton of this alloy of gold, silver, iron, copper, etc. If you have no tenth grain, divide one end of the lever into ten parts, and make a rider grain weight by bending a small piece of wire, or dry twine, into the shape of a horse-shoe, when each mark will represent a tenth grain, and one ounce per ton. If your scale is a very common one, take ten times this quantity for "assay ton," and every grain will represent an ounce.

B. If it be desired to have a button of gold from this residue, by fusion with machine, place the fine gold in one of the prepared charcoal supports, cover with a thin layer of borax glass, this again by a thin layer of say 20 grains of test lead, and, after lowering the suspended covering of charcoal as close down over the assay as practicable, smelt, by carefully increased blast, into auriferous lead, and cupel as described in the fifteenth mode, for the silver assay, by machine. This will still be an alloy of the pure metals, gold and silver, which can be *approximated by the practical eye for carat value;* but, if gold is correctly required, it must be parted as described towards the end of this chapter (under No. 24), by acids.

C. Amalgamate with mercury, sublime or retort, and smelt as under No. 11; or by machine, as above.

13. GOLD AND SILVER ASSAYING BY COMMON BLOW-PIPE.

Pulverize and mix your sample with even more care than before; take about five grains therefrom, which place in an

agate mortar or saucer, and grind it still finer with the pestle, or small flat stones, to an impalpable powder. Next weigh, from the mortar or saucer, just one grain for the assay (which is as much as the common blow-pipe will successfully reduce); with this intimately mix its weight of borax *glass*, and six times its weight of test lead.

Prepare a cartridge—or, better, a few dozen spare ones—by cutting oblong strips, 1$\frac{3}{4}$ inches long by 1 inch wide, from soft *bulbous* letter-paper, which soak in a saturated solution of carbonate of soda; after these strips become dry, roll them on the butt-end of a common pencil, that is one-quarter of an inch in diameter, so that sufficient may also overlap to form the bottom of cartridge; moisten the last folds of the side and bottom with flour paste; then take off, and dry for use. Transfer this weighed, fluxed, and leaded sample to an empty rifle cartridge, sewing thimble, or more suitable scoop, if you have it, and mix it thoroughly together with a needle, very small and smooth twig of wood, or smoothed match. Select a good piece of charcoal (white pine and willow are best), free from cracks, and of the size and shape of the largest new cork for a wine bottle. The willow coal is most readily shaped by simply cutting off the branch as it grew, into lengths. Into each end (so that it may serve twice) drill, with a suitably sized charcoal borer, a sharp knife, or sharpened piece of hard-wood, a central hole, a *little larger* than the prepared cartridge, and a quarter of an inch deep; place it therein, and thus supported in the charcoal, which vertically rests near the edge of a clean table, carefully sweep the sample, with what may have dropped on the table, with a camel-hair brush, therein; add 3 grains more of test lead, on the top, and fold the surplus paper well down over the enclosed sample, for better resistance of the first effects of the blast, during smelting.

Next learn to blow the whole of the flame of the candle or lamp before the pipe, *without any cessation*, for fifteen minutes, and, when you can do this efficiently—which practice alone can realize—you may proceed with the assay as follows.

Take into the left hand the charcoal support, which contains the cartridged sample, and surround it by the thumb and all the fingers, in such a manner that the assay may be

held either *horizontally* or *diagonally*, whilst it is being also *turned by the fingers on its own axis*, as most desirable. This will also require some considerable practice.

When these can be properly performed, closely trim your olive-oil lamp, so that no stray fibers shall cause imperfect combustion, before its flame is at maximum strength; place the lamp at suitable and convenient distance and height before you, so that all the imperatively necessary manipulations may be most readily performed.

Now, with a gentle pressure, blow the blue flame upon the horizontally held assay, until the upper lead melts and becomes safely ensconced in the molten slag; next *gradually increase* the blast, *incline* the assay towards the nozzle, and *enclose it in*, or *cover it by*, the point of the *whole mass* of the yellow flame, so that the ore may be *reduced* as quickly as possible to metal, by the greater heat thus produced, and the exclusion of atmospheric oxygen.

During this reducing stage, three things must be more particularly noticed.

1. That the pressure is not too much, nor too little, but such as is seen to be, by bright combustion, most suitable for maximum heat.

2. That the lead is *red hot*, and travels freely *around* and *through* the mass of slag, at your pleasure, by suitable twist and inclination of the support.

3. Towards the close of this smelting operation (which generally requires from eight to fifteen minutes), most particularly observe that the scoriæ becomes "orbicular;" or, more intelligibly, that the molten lead button is partially enclosed by the mobile, supple slag; as the ball of the eye is by its lid.

This, when cold, may be most easily separated and cleaned, by being enclosed in a small piece of rag, or a few folds of paper, (which safely retains the whole and effectually releases the lead from its slag), and thus hammered flat. The lead is now again hammered into a cube, and further cleaned with a tooth-brush, for more perfect cupellation.

A small recess may be cut into a piece of charcoal (the space left after smelting the assay will often do), and filled with moistened bone ash, which may be compressed into a

smooth pit with a tea or salt-spoon, if you have no more suitable tools, and then slowly dried for the cupellation of button.

This is next warmed before the blow-pipe's flame to *redness*, and the lead being put thereon, after it is rendered *red hot*, or *molten*, in the reducing flame, it is held *beyond the tip* of the small and *conical blue flame*, for oxidation of the lead and other base minerals, and consequent purification of the precious metals, gold and silver.

This operation is completed when the peculiar appearance of the button of silver or gold, called "brightening," is exhibited, which had better be practically studied before blow-pipe, on small, known sized, silver and gold buttons, purposely alloyed with lead. (See "Cupellation of Button," from crucible assay of gold and silver, in Example 1, of this chapter, for its appearance.)

14. WEIGHING OF SMALL BUTTONS.

However difficult the smelting and cupelling manipulations for the assay of gold and silver by the common blow-pipe may be, that of weighing the resultant button is even more so; and, as it has not been previously elucidated, it is therefore eminently worthy of some especial observations regarding these practical difficulties that have to be encountered, as well as the best means for surmounting them.

The Berzelian glass-cased portable balance is the most convenient and best for minute weighings. The lever is poised on a very delicate knife-edged fulcrum, which rests on jewels that are supported in, and rocked by, a pendulous cradle, that, under all circumstances, settles in vertical and accurate position. This cradle (which is its best characteristic) supports the whole scales, and is attached to, and suspended from, a square bar, that, by sliding in a suitable socket, hoists or lowers the pans off from, or on to, the bed-plate, during the operations of weighing.

The warranted weights that are made by Oertling, of London, are most reliable and convenient, which, by ranging and decimating from 1000 grains, through 100 grains, to 10 grains, to 1 grain, to one-tenth grain, and to one-hundredth

of a grain, affords every facility for varying the *quantities* that are required for water, chemical, volumetric, crucible, scorifier, and blow-pipe assays; as well as their respective advantages for decimal calculations by their five units, for hundredths, thousandths, or two-thousandths division.

To weigh a silver or gold button, that has been produced from a one-grain sample, it will be first necessary to prepare, and examine the action, of such a new scale, as to its susceptibility; which may be done in the following manner. Take out the beam, lay it on a board, and carefully mark off its right half, with a square and compass, into ten equal parts, by scratching its nearer edge and side with a needle's point; and these again into tenths, by shorter and less distinct lines, and its left half into twenty parts for pennyweights.*

Replace the lever, and make a weight from a very small and dry white thread, so that it may exactly equal the smallest of the Oertling white aluminum weights (one-hundredth of a grain); bend this thread weight to a right-angle or L shape, for a rider-weight.

Fix permanently a brass or tin-plate tube, that contains a lens, to the upper part of the glass case, in such a manner that you can distinctly read the magnified motions of the cradle pendulum, that carries the scale of degrees, and that of the pendulous pointer from the beam to these degrees, both when the glass door of the case is open, as well as when it is closed.

Elevate your scales by the thumb-tackle, so that the pans may be about one-fourth of an inch above the bottom of the

* This can be most readily and correctly accomplished by drilling a hole, about three inches from the left-hand *straight* edge of a suitably sized board, to snugly receive the knife-edged central axis of lever, when the beam must be placed, carefully fenced in, and firmly secured by small tacks, in a position just parallel to the edge of the drawing board. Next take one side of an ordinary cigar-box, and, after pasting thereon a white sheet of paper, mark, by cross lines, the exact positions of the centre and end knives of balance lever, and divide the one end, also by cross lines, into equal tenths, and the other into twenty parts; and then, by other lines, first drawn parallel with beam; then divide across the first end by diagonal lines (drawn from one to two, etc.) into tenths, and the last into four, or twenty-four parts (for reasons described), and, assisted by the square, and a needle for pegging position, scratch with another needle corresponding marks on the beam of scales, so that they may be distinctly seen when using the rider.

case, and scratch a mark on the square bar that elevates the scales, so that they may be always raised to the same height. Drill with a brad-awl two holes in the bottom of the case, on the nearer side of each pan, and turn two pieces of wire into ⊏ shapes, so that the limbs of the ⊏ being placed downward, they may be forced into these holes, until the back or body of the letters shall form transverse bridges in front of the scale-pans, about three-fourths of an inch high from the bottom of the case.

Break a piece from off the *end* of an old clock's main-spring, about two inches long, on which the eye remains, and force the plain thin end in the joint formed by the wood at the top of the glass case, so that the bow at the other end may gently spring on to and hold the glass door, when it is necessary to be retained thus elevated. This is much better than the silken loop and brass pin that are supplied with the case for this purpose.

Being thus accommodated with facilities, you had better sit before the instrument, and study for awhile the natural motions of the pointer, and pendulous cradle, that carries the graduated ivory scale; and notice more particularly that their oscillations should be regular, long continued, and gradually lessen to a very slight movement, before final settlement. Now take a piece of very thin glazed paper, and cut a strip therefrom of about the width of a pin, and transversely cut from this strip other very short pieces, to bring the beam to balance by placing them in either pan, as may be required. Read these magnified minute motions scrupulously exact, and be sure that the scales are properly balanced, before weighing any very small quantity, for value.

Having proceeded thus far, cut off from the same thread of which the rider was made, a piece of only one-fifth its length, and, after observing that the pointer is still straight with the mark, drop it into one of the pans, without lowering them, by gently tapping the forceps on the transverse wire bridge in front.

If this turns the beam, and is seen by the pointer, it may be sufficiently near for your purpose in the silver assay ($7.54); but, if it does not, you may make the beam more

susceptible by carefully operating thereon, at your own risk, as follows.

Unhook the pans from both ends of the main lever, and *gradually and carefully* file or scrape the pendulous pointer lighter (which lessens the distance between the centres of gravity and floatation), until it will do so; which is, however, a somewhat dangerous operation, for it may, when over-acted, render the balance wild and irregular in settling; this, however, may be cured by putting on a small silver or gold globule over the lower end of the pendulous pointer.

I have a balance of this kind, prepared in this manner, that turns with half this quantity (the one-ten-thousandth of a grain, which represents $3.77 per ton, on one grain assays), as is recorded by the thread rider, when it is moved but a one hundredth mark on the lever.

The balancing by small pieces of paper is a slow and tedious affair, which I have avoided by fixing a weak magnetic needle in a suitable side position, at the proper height in the case; so horizontally swivelled on central and side pivots, that the slight positive and negative powers may be applied at varying distances, to attract or repel, as required. It is prompt, effective, and exact, as well as a great comfort in use.

Having ascertained that your scales are sufficiently exact, you may now take the button from the bone ash, by holding it on edge in a clean saucer or plate (which is much better than paper, because the latter springs the button away, and it is often thus lost), and gently remove it by a judicious twist with a pen-knife. After this minute button is cleaned to your satisfaction, which can be seen with a magnifying glass, move the plate or saucer close to the scale-box, see that the beam is still balanced, and take the button in the forceps at about an eighth of an inch back from its point (which should be filed taper), and carefully transfer it with the right hand to the left-hand scale-pan, by tapping *very lightly* on the cross-bar in front.

Now place the white thread rider on the other (graduated) end of lever, with the forceps, without jostling the lever in the slightest degree, and move it until the pointer again indicates exact equilibrium, as before. All this must be

done, for very small buttons, with the pans *suspended all the while*, from the first empty scales' balance to the completion of the weighing of the button, as the slightest movement, by changing the point of rest, destroys equipoise.

It will be always advisable to at least repeat the balancing and weighing, and lastly to check, by placing the rider on this supposed truthful position first, and then to merely drop the button into the suspended pan, for positive results.

If the button weighs less than when this rider is on the first tenth mark, the beam may be first *balanced* with the *rider on this mark*, and the button being then dropped into the pan, its weight may be more easily and correctly read, by the *additional length* that the rider is *moved outwards*, to re-balance it.

Use the same scale-pan for weighing the button as you did for the assay, so that any difference in the lengths of the lever ends (which is often the case) may not cause incorrect results. (See under the twenty-second heading of this chapter for the weighing of parted gold.)

To calculate the value of such a button, when obtained from a one-grain assay, let one-tenth of the weight of this thread rider, which is one-thousandth of the one grain, stand for an unit of calculation, as previously explained, which may be either directly multiplied by 29.16 for ounces, or by 37.7 for dollars per 2000 pounds ton; or you may multiply this weight, as obtained from 1000 such units, by 2, to show what a double smelting would have given, which would be exactly that of or from the 2000 assay ton, which, by being multiplied by its multipliers of 14.58 for ounces, and 18.85 for dollars, will realize the same amounts.

Having made yourself thoroughly certain of what constitutes the unit, or first whole number, for the different quantities taken from time to time for the different modes of assay, you may refer to the following table of multipliers, which, as you will see, is founded on the foregoing explanations.

If 2000 grains, 200 grains, 20 grains, or 2 grains, be taken for the 2000 pounds assay ton, each unit or pound (of two-thousandths the weight taken) must be multiplied by 14.58 for ounces per ton of gold and silver, and by 18.85 for dollars in silver, and by 301.36 for dollars in gold.

The multiple for the coin value of any nation may be found by simply multiplying any *unit* of weight by the desired money it will realize.

Where the ton is not capable of direct decimation, or variable, such as the English, it is better to take 2240, 2352, or 2300, as the case may require, of such assay pound units, for the assay ton, and use the above multipliers.

These multipliers may be then tabled as follows, to suit the required fractional quantities taken for different methods of assay.

For 1 assay ton, the *assay pound* x14.58 gives the ounces of gold and silver per ton.

For ½ assay ton, the *assay pound* x29.16 gives the ounces of gold and silver per ton.

For ¼ assay ton, the *assay pound* x58.32 gives the ounces of gold and silver per ton.

For 1 assay ton, the *assay pound* x18.85 gives dollars in silver, and x301.36 dollars in gold.

For ½ assay ton, the *assay pound* x37.7 gives dollars in silver, and x602.73 dollars in gold.

For ¼ assay ton, the *assay pound* x75.4 gives dollars in silver, and x1205.46 dollars in gold.

These multipliers will be all that you will require for quantity taken; and for *any of the tons*, if the number of *assay pound units* are taken that *constitute such different assay tons*, when decimated weights are used. I have covered considerable space to explain these technicalities to the amateur, because he is supposed to know but little of these matters; and I hope that I have succeeded in rendering them sufficiently clear to his view for all practical purposes. He must not forget that the principle of calculation hinges entirely on the assay ton and assay pound, the latter being the unit for calculation; and that where the above fractions of the tons are used, the same unit is retained, and consequently the multiplier must in all cases be equal to that used for the full ton, multiplied, when it can be, by the *denominator* of the *fraction* of ton taken, as that of the last, for the scorifier, where the first, multiplied by 4, equals the last multiplier.

Or it may be done for *any quantity*, as a compound fraction, by inverse proportion, thus: If 2000 pounds require the multiplier of 14.58 for ounces per this ton, what multiplier will 500, *or any other quantity*, require, to ascertain its value per ton in ounces? It will require a larger multiplier, as already shown, so that $\frac{2000 \times 14.58}{500} = 58.32$; so, for dollars, $\frac{2000 \times 18.85}{500} = 75.4$.

He will also remember that any of the units may be taken, where it is of suitable weight for making an assay ton of the right weight, from the correct number of such, to suit the method of assay. For instance, the crucible assay may be made from 2000 grains, or 200 grains, or 20 grains, because you can very readily divide into the 2000 units in each case; whilst 2 grains can be also thus divided, for the principle of figuring, in the half-ton taken for the one-grain blow-pipe assay, when calculated by the rider, as explained.

English readers may take any one of the tons, as 2240 pounds, for assay ton, and any suitable unit thereof for assay pound, to suit the kind of assay, so that the unit or number of units, or assay pounds, realized, being multiplied by 14.58 (the number of Troy ounces to the avoirdupois pound), the Troy ounces per ton can be ascertained, and the money value be also known by multiplying the ounces per ton by the value of the silver or gold, according to the fineness of the button, or rates given for fine gold, or silver, at the time and place. (See heading 4, for suitable assay ton, for self-calculation, and subdivision into ounces and pennyweights, by rider on suitably divided beam.)

So also may the value for the one ton be easily obtained, by proportion, from any known value of the other; as, supposing the 2000 pounds American ton yielded 3.12 ounces, the 2240 pounds, or any other English ton's value, may be known thus: The 3.12 ounces, multiplied by the 2240, and divided by the 2000, will show the corresponding yield of such a ton to be 3.494 ounces, etc.

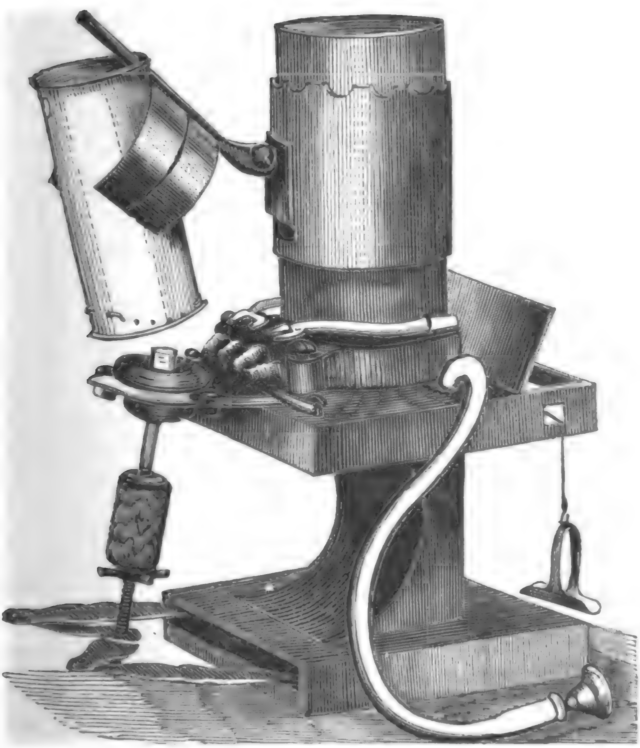
In skilled hands, with good tools, when in comfortable quarters, the common blow-pipe is excellent for the *testing*, and, *when accompanied by very superior scales*, even *assaying of silver ores*, which can be *mixed to a fair average;* but, for *gold*, that is always so *irregularly deposited* in *metallic nugget* form, and

which *cannot* be equally mixed, it is *most absurdly ridiculous* to smelt but *one grain* for *average assay information*, even were it possible to weigh and value the *minute* resultant button. It is, however, very correct for the thousandths fine of gold, and silver bullion.

15. THE ASSAYING OF SILVER BY DIRECT SMELTING AND CUPELLATION, WITH THE EXPLORER'S "WEE PET" MACHINE.

Erect the machine for general purposes, as described at Chapter IV, on Discrimination, and as here illustrated.

Cut 21.



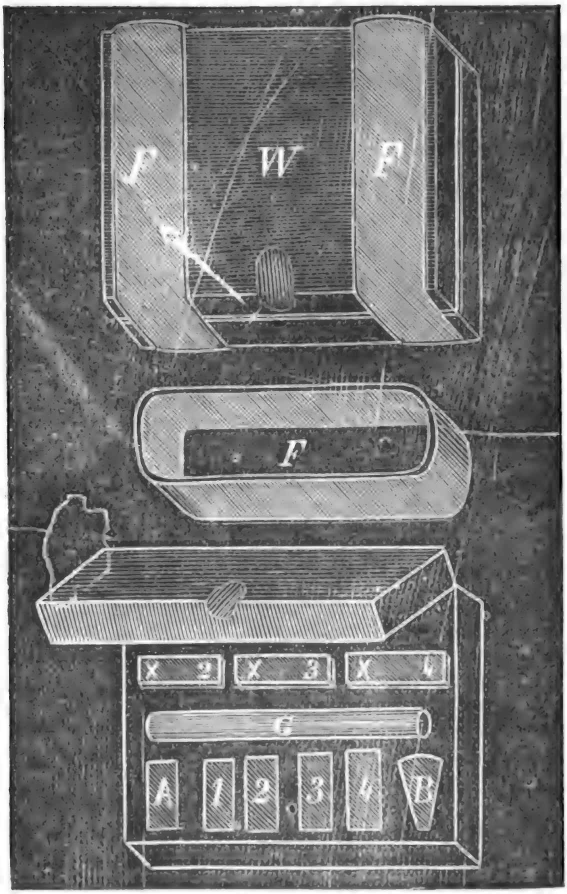
Pulverize and faithfully prepare the sample, as described in Chapter I of Section III; be very careful to obtain as perfect an average as possible, and if the sample is from a district that yields chloride, or metallic silver, the upper side of the sieve must be closely observed for flattened disks, as

there more particularly described, so as to conduct your operations and collateral calculations accordingly.

A. Place the machine in a level position on the ground, a rock, or a table, with the weighing and calculating lever

Cut 22.

These numbered weights are intentionally contrived, to weigh, by incremental differences, with the balance weight A, and must not be fingered, or rubbed in any other way.



The weights are enclosed between the chamois leather lining of the box; and are thus kept clean, quiet, and secure, during traveling, and also when not actually required for use.

transversely before you.* Take the box that contains the weights from its compartment in the flux-box, that may be seen (marked W, Cut 22), and, keeping the side that is *marked* on top, slide off the brass fasteners (F, F, Cut 22),

* This, and the other eighteen novelties, of the "Wee Pet" Assaying Machine, have been secured by Letters Patent, dated 7th September, 1869.

and, whilst the bottom *rests on the table*, open and turn its lid also *over* **and** *down* on the table (as Figure 2, Cut 22), so that it may rest securely in position.

B. Now take the lever out of its box; place the knife-edged fulcrum on its glass supports, so that the short end may pass out with its hook at the right-hand end, whilst the long end protrudes its pointer through the left-hand end of the box.

C. Square the bow of the scale scoop, and hook it under the short end of lever (as in Cut 21).

D. Close down the cover of the tool-chest, that lies under the scales, and wipe its upper side perfectly clean with a rag.

E. Take the balancing and assay weight marked A, that equals 10 grains, and lies on the left end of the box, into your forceps, and lay it on the cleaned lid of the tool-chest, with one end slightly overhanging the lid towards your hand, ready for transferrence to scale-pan.

F. Now, with the *left hand resting on the table, rock, or ground*, for a *fulcrum*, or *central rest* (to prevent shaking), take the *over-lapping* weight A from the lid with the right hand, by first *resting* the right hand on the *left hand*, and entering *one point* of the pliers under the said weight, and gently moving your whole arm and body downward, as if the *fingers, hand, wrist, and elbow, from end to end, were a solid lever of cast iron;* as soon as the weight is slightly lifted, close the thumb (which is the only joint supposed to be free) down upon the forceps (with the whole arm still rigid), and the weight will be lifted in the most steady manner that is possible. Place it with equal care into the scale scoop, by reversing these movements.

G. Place the lever in correct position, so that it may vibrate in the middle of each end hole, with perfect freedom from top to bottom, and waft the hand down over the pan, or blow down with gentle breath, so that the lever may be encouraged to oscillate equally, and continue to settle in the same position, the terminating pointer of the long end being about one-sixteenth of an inch above the bottom of the opening.

Cut 23.

H. When you are satisfied that this action is fairly produced, move the small *cross-lever* until the *line* on its short end stands *opposite the pointer* of the *long lever*, and cause the latter to move up and down, as before, a few times, to see if it settles, as it should do, just opposite the mark, and, if it does not, move the short lever until it does.

I. It being thus correctly balanced, remove the balancing weight A, after the manner explained under letter F. You should practice this several times, until you can prevent jostling, and continue to balance the lever by removing and replacing the weight several times in succession, yet still repeating the pointer to its true position opposite the mark.

J. The weight may be taken out of the pan, and the sample for assay taken from many places in the prepared pile of ore, that has been pulverized between two hard stones, sifted through sieve (Figure 3, Cut 23), and bruised to an impalpable powder, by pestle and mortar (Figures 1 and 2, Cut 23), as in the last example for common blow-pipe assay of one grain; this ore is put into the pan until the lever again balances, when it will, of course, equal the weight A, and is also 10 grains. This may be now either treated somewhat after the manner of scorification, as K 1; or as under heading K 2, by cartridge, etc.

K 1. Place the one weighing of 10 grains of ore in the moulded or whittled charcoal support, and three balancings, or 30 grains, of litharge therewith, which mix intimately together, and then cover the whole with six balancings, or 60 grains, of test lead, and smelt with a gradually increased blast for from fifteen to twenty minutes (as directed under headings T, U, V, W), and then refine the button as instructed under heading Y (for cupellation).

In this method, which is much more simple, and requires no paper cartridges, there are four effects produced.

1. The mineral is cemented, and fused with litharge, by a *gentle blast*, which effectually prevents loss.
2. It is oxidized, and smelted at full heat into alloy with the lead.
3. This alloy is partially oxidized into litharge, which

forms a very fusible slag with the matrices, and reduces the weight of lead for cupellation.

4. It is cupelled and refined on bone ash, as under Y.

In *fusible non-refractory silver and silver-lead ores*, 20 grains may be treated with ease, by this more capacious method, which has advantages over the scorifier of the concentrating effects of the flame on every part of the assay, that is being constantly turned round, whilst the lead button is thus encouraged to travel through the mass, and collect every particle of silver or gold that may be contained therein.

K 2. Take from the side chest, with the left hand, one of the fluxed and pasted paper cartridges; after weighing 10 grains of ore, as before, unhook the scoop with the right hand, and, with the cartridge in a horizontal position, first enter the scoop therein, and then, by elevating the cartridge, and tapping the scoop with the finger, its contents will drop or may be brushed therein.

L. Weigh the same weight (10 grains) of borax glass, from the right-hand wing compartment of flux box, and add it thereto, in similar manner.

M. Weigh six balancings (60 grains) of test lead, and two weighings (20 grains) of litharge, in the same manner.

N. Intimately mix these together, by simply stopping its mouth or opening under the thumb, and holding and shaking the whole contents between the thumb and finger, as you would a small bottle of medicine.

O. Fold the surplus paper snugly down over the ore, place it in the charcoal support, and it is ready for being smelted.

P. These cartridges are made by being first cut into oblong strips, four inches long and one and a half inch wide, from tough and somewhat bulbous brown paper (such as is used by miners for making blasting cartridges, when sinking wet shafts, will do); they are then *soaked for an hour* in water that has been *saturated with carbonate of soda* (with as much of the carbonate of soda as the water will take into solution), and to which *as much sugar has been added after this saturation* as the water will *then liquify*. They are next slowly dried,

and, when quite dry, folded on the handle-end of brass charcoal borer (Cut 23, Figure 9); at the same time they are turned over its end, firmly pasted with starch or flour, withdrawn (as Figure 10), again dried, and stored for use when required.

Q. Take one of the *moulded charcoal supports*, or an exactly similar one that has been "whittled" or filed to suit the bell-cup, and shaped on its upper side with the appropriate charcoal borer (Figure 9, alluded to under paragraph P), from a good and solid piece of charcoal, either of which place in the bell-cup, and turn the *machine* to the position shown in the cut.

R. The assay supports are moulded from a composition of

Finely pulverized charcoal....................	30	tablespoonfuls.
Carbonate of soda................................	4	"
Common *store* borax (not borax glass)... ...	2	"
Sugar or molasses........	2	"
Rice flour, corn or wheat starch..............	1	"
Water sufficient to mix for moulding, about	16	"

Take a baking-dish, or prospecting-pan, and first place therein 16 spoonfuls of water; into this water throw 4 of carbonate of soda, 2 of commercial borax, and 2 of sugar or molasses, all measured to the brim, like the water, by being struck off level by a knife; warm over a fire, stir until the ingredients are dissolved; then add the rice flour, and stir until it boils, and the liquid becomes, from the softening of the rice flour, somewhat paste-like. Take it off from the fire, and, after it is cold, add the 30 tablespoonfuls of charcoal; then mix, and well knead it, as you would dough for the crust of a pie. It is sufficiently wet when it just holds together in the hand, after pressure.

S. Take the bottomless bell-cup, that is of similar size and shape to the assay-supporting holder, from the long toolchest; place it on the thin brass bed-plate (Figure 4), that resembles the shape of the top of assay support or coal (like Figure 5); then fill it tightly with the composition, by pressure of the thumb and a small ramming stick, and insert on the top of the moulded coal the small cheese-shaped brass

disk (Figure 6); after hammering it down fair and square with the top of external mould, rest your right thumb vertically thereon, twist and raise the bell-cup mould up over the thumb, and lift your right thumb away from, and take off, this brass covering, by a twisting motion. Invert the coal and bed-plate (Figure 7) into the left hand, and carefully separate, by a twisting, steady movement of the right hand, the brass bed-plate therefrom, and after placing them on a stone, to dry slowly before a fire, sift on the assaying side (which should now be on top, as Figure 8) a little dry carbonate of soda, and, after they are slowly dried, they will be ready for use. If the mixture is of suitable moisture, there is no difficulty in making them, and, as they are fluxed and do not crack, they are better and much safer in use than charcoal.

T. The folded fluxed paper cartridge that contains the ore being now put in the moulded fluxed support, place the handles of blast pipes into the main blast holes; the wind being thus securely stopped, blow in a full breath into the machine, to elevate the water in the upper cylindrical column, where it should keep its level, if all is well; if it *does not*, see Chapter IV, on that subject. With the water thus *kept at the maximum height*, light the four wicks, and see that they are neither too tight nor too loose, and that they are suitably trimmed, opposite to, and in line with, the blast pipes. The oil chamber should be also *quite full of oil*. Allow the wicks to burn well up before commencing blast, or they will be slow in doing so, when nipped by the blast.

U. Fix a piece of good solid charcoal in the four spring-fingers of suspension lever, and lower this part of the machine down over the assay, as shown, to within the fourth of an inch of the top of the assay paper, at such an angle as will not obstruct or divert the flames before the nozzle's blast, the objects being to cover, and thus prevent radiation and increase combustion, but not to actually receive the blowpipe's flames, which must concentrate on the assay, and bottom or bed coal. If you have no large piece of charcoal, you may suspend the cylindrical furnace (as seen in Cut 21) to this spring lever, and supply it with small pieces on its firebars, as required for this purpose.

V. Now see that the blast pipes are all clean and clear; and, if they are not, just wipe them with a rag, or clear them with a needle that is *smaller* than the *holes*, and which has had its *temper destroyed* by having been made *red hot* in the fire or in a flame. These *two things must be scrupulously observed*, or you will *enlarge* or *choke* the holes, and *disable* the machine. Replace them in blowing position.

W. Sit down, if the machine is on a table; or, if no better place can be found, spread your blanket on the ground, and lie thereon, with your head on the saddle for a pillow, so that you may take hold of the cork on the stem of the assay cup with the left hand, and be in a position to see the progress of smelting, and to blow an occasional lungs-full of wind into the machine when required. We will, however, now suppose that it is either on a suitable rock, on the edge of a prospecting pit, or on a table, and thus the smelting proceeds.

Place the wick-lever at its inward limits of travel, so that the blue flames shall concentrate on the assay. At first, for some two or three minutes, *blow very gently* into the machine, and see that the flames play correctly on the sample; if not, move the support by the cork on the stem, either towards or away from you, by the horizontal spring-levers; or up and down, by the diagonal screw.

The assay may be kept almost level now, must be occasionally turned round, and the flames need not be continuous just at this time, which is the roasting and oxidation period; so that you have time to consider your movements, and fix things in order for the smelting proper, without interfering with the perfection of assay. Now *move the wick-lever outwards* to its *terminus of travel*, so that the four full yellow flames shall *concentrate on* and *cover* the assay, whilst the suspended coal should also be lowered as close down over it as the routes of the flames will permit.

The currents of wind from the nozzles should not travel exactly *through the centres* of the flames, as the flames are then liable to be *extinguished under strong blast;* and therefore, if such should occur, you can bend the intermediate wicks inwards a little, and the end wicks outwards just sufficient to

prevent it, without injury to the flames, from the pipes to the assay.

Now blow an occasional full breath into the machine, and notice when the flames begin to weaken, so that you may renew it before they stop: it will, perhaps, be better for you, until you become familiar, to blow in a full breath, and then draw two or three comfortable breaths between each supply of air to the machine.

Take particular notice when the greatest heat is produced, and that it concentrates immediately before and on to the assay sample. Now the smelting proper begins, and the flames must be not only continuous, but well directed, and of the greatest possible heat. Turn the assay cup slowly about two rounds one way, and then two rounds the other way, to give all sides of the assay a fair chance, and to keep it at a proper height in the centre of heat. The lead buttons will by this time have commenced to aggregate into one, which will now travel around the slag, and you must encourage this traveling around and through the scoriæ as much as possible, by *gradually inclining the stem and assay*, so long as you are satisfied that it will not roll overboard, and be thus lost. When the smelting is well performed, in from eight to fifteen minutes after these yellow flames have been thus continuously blown, the slag becomes supple, the button of lead is reddish, and travels freely through and around the slag, whilst the slag partially encloses the molten button, just as the lid does the human eye. This is a mark of success; and the assay button may be laid aside until quite cold.

If the slag is thick and immovable, or much scattered, its condition can be bettered by collecting or stirring it with a small twig of wood, held in the right hand, whilst the flames are still playing thereon.

The following must be always obtained: Good oil, and well trimmed wicks; good supports, with the assay well centred in the heat; the blowing must be so studied that the greatest heat is produced; the covering of charcoal must be positioned correctly, for this is the most efficient cause for effectually treating such a large quantity.

The long furnace, with iron bars at the lower end (as seen in the assay, Cut 21), will be found very serviceable, when

you have no large pieces of charcoal to suspend in the elastic fingers, for it may be simply attached to, and suspended by, the round handle of lever over assay; and the furnace may be supplied to about two inches deep with several small pieces, of the size of beans, that, thus supported on the small fire-bars, can be lowered down just as effectively over the assay, both for smelting and cupellation. It will be generally found more convenient, and always more practical, as well as economical.*

The lead button or buttons, with the adhering slag, may be cleaned by being wrapped in a strong fold of paper, or in a rag, and made ready for cupellation by being hammered flat, so that the lead can be properly cleaned and solidified into a cube, as previously described for other assays.

X. Whilst the button is cooling down, the cupel may be placed in the hot cup, and the covering of charcoal, or the upper furnace, lowered over it, so that it may become dry, hot, and ready, by the time the button is cleaned.

These cupels may be also made in two ways; the first for immediate use, by squeezing moist bone ash into the concavities at each end of the brass mould (Figure 21), and further shaping and smoothing them with the suitable con vexed bed and top plates (Figures 20 and 22). The one end must be filled, compressed, and smoothed; and then, by inverting it on the table, or rock, without taking off the smoothing and shaping plate, the second end can be filled in the same manner; and then, after the two brass shaping plates are removed by a suitable twist, the central double cup, that contains the bone ash (Figure 23), may be placed into the assaying bell cup, and dried for use. The second method of making cupels is by placing the cylindrical mould (Figure

* The heat and consequent smelting power may be much increased by a simultaneous central jet of either hydrogen or oxygen gas, made for the purpose, and supplied as highly inflammable tributaries to the regular currents of burning gases from the olive oil lamps of machine. By having a *nozzle for each gas*, they may also be separately made just when required, and ignited without danger of explosion, to produce their well known combined effects.

Or a vessel of alcohol may be warmed, beyond the assay, and its vapor may be conveyed by a turned pipe and suitable nozzle into the centre of the currents from blow-pipes. Air may be also passed through gasoline.

12) on the larger (Figure 13) bed plate (as Figure 14), and, after filling it with compressed moistened bone ash, to make the short ram (Figure 15) form the upper end concavity, by causing it *to just enter therein* (as Figure 16); and after placing a piece of wood upon it (to prevent its being injured), to force it down with a hammer or stone, so as to make it sufficiently tight for its purpose; and then, after taking off the bottom by a twisting motion, invert the mould, and, with the flat end of the ram (Figure 15) resting on the table, twist the cylindrical mould (Figure 12) gradually down to rest also on the table, when the naked cupel of bone ash (as seen in Figure 17) may be gently removed with the fingers (Figure 18) to a convenient place to dry, for use when required. Such had better be used when you are fixed in comfortable quarters; but they are too fragile for traveling purposes.

Y. The Cupellation of Button by Machine may be performed as follows. With the wicks as they were for smelting, and the covering of charcoal close down over the cupel, blow the flames thereon until it becomes red hot; then place therein (without stopping) the cleaned and hammered button, which will almost immediately settle into a molten semiglobular shape; as soon as it looks quite molten, clean, and bright, having no slag or oxide encrustation, draw the wick-lever almost close into the body of the machine, so that the *two nearer flames* shall be *small and blue*, whilst the others are a mixture of yellow and blue.

Remember that *just sufficient heat* must be given to the *button to keep it molten*, and to the *cupel* that the *litharge, or oxides of lead, etc., may enter therein without freezing on the surface, or clogging its pores;* and also that *oxidation is facilitated by excess of air*, when accompanied by *sufficient heat or fluidity.* These effects may be attained by paying proper attention to the position of button, which can be varied at pleasure by the stem screw, the covering of charcoal, or by the transverse motion of spring levers from the twin yellow (heating or reducing) to the twin blue oxidizing flames. This latter may be modified, or better performed, by appropriate oscillating twists of the cupel by the cork stem. The cupel need to be but partially turned occasionally during cupellation, so

that other parts of bone ash may be heated, to absorb more of the base oxides. You will here again notice what manner of blowing will reduce the size of the button quickest, and will be advised to produce either *voluminous fumes of white oxide* before the *excessive blast*, or the peculiar *wave-like* oxidation from the surface of button into the bone ash, when it is held *half within* and *half without* the flame; or the both.

You will have no difficulty, however, in oxidating the base metals off slowly, and a little practice will increase speed.*

Until you become perfectly familiar with the appearance of silver and gold buttons, you had better first cupel it down to the size of a duck shot, on the one side of cupel; and after taking it off, and thoroughly cleaning it with pliers and brush, to finish its cupellation on the clean side of the *red hot* cupel. In this way, the clean ash will in a manner provide, or dispense with, the necessary intelligence for purification.

The pure button of silver should be frosted silver-white, and expose one or more warty protuberances.

When the cupel is quite cold, lay it on its edge, in a perfectly clean plate or saucer; release the button from the bone ash, by a careful twist with a pen-knife's point, and clean it by a squeeze of a clean pliers and brush, or by rubbing it on the plate with a piece of hard and smooth white paper, until it is sufficiently clean for valuation.

Z 1. TO ASCERTAIN THE VALUE OF THE BUTTON BY THE CALCULATING LEVER, AND BY THE DIVERGING STRIP TABLETS.—Balance, with weight A in the pan, the main lever's pointer to settle one-sixteenth of an inch above the bottom of the opening, and move the appropriate transverse lever's line to agree therewith; this do with the most conscientious care, as directed under the letters A, B, C, D, E, F, and then remove the weight A from the pan so gently that no injurious motion will be communicated to the scoop and lever. Next place in the scoop one of the nearest plainly numbered weights—say No. 1—and drop the button, by laying the forceps

* A 200 grain button of lead may be cupelled, after you are fully acquainted with the mode; so that you may smelt twice, thrice, or four times, and cupel the several buttons together: a crucible or scorifier button, or lead bullion, amalgam sponge, or granular and fine gold, may also be alloyed with lead, and thus cupelled and purified.

gently down on the edge of box, into the groove of the long end of the lever, just over the figure, in the columns of figures, that will pay for being worked by milling, smelting, etc., and again see if the pointer is above or below the line on the transverse lever's line; if it stands above, the assay is too low for its being worked profitably, and what you require is already known. If you desire its exact value, move the button outwards, by a *small piece of thread*, about a *half-inch long*, that has been *inserted transversely in the cloven end of a small sprig of wood*, until the pointer stands exactly opposite, or the next less weight is required to balance for value. If, on the other hand, the silver button affords more than the expenses required for working the ores, it may be carefully moved inwards by the thread, until you are informed what its value is on the No. 1 column, or any other numbered weight and column (as seen on Figure 1, Cut 24).

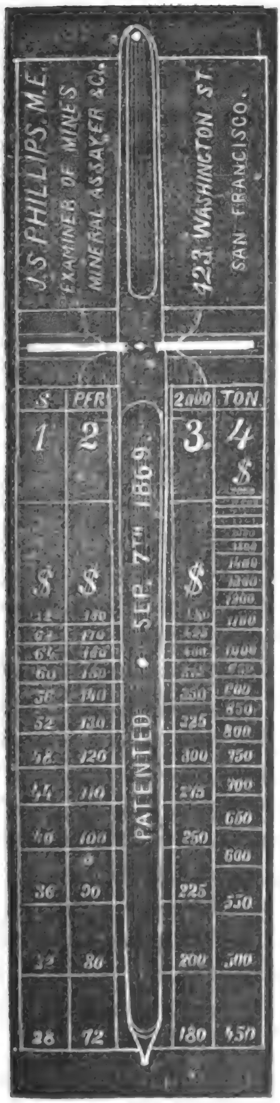
If it passes *still further in* than the *highest figure* in this column, you may judge what larger numbered weight will be required to perfect the lever's balance, and very carefully substitute such weight for the No. 1 in the pan, and again move the globule to balance. It may be so large, and you so fortunate, that even the largest plainly numbered weight will be insufficient to balance it, when one of the weights marked X 4, etc., would be required; if so, balance the pointer with the suitably numbered weight, and read *ten times* as much as the figures underneath the button in the same numbered column (4 in this case), by adding a figure 0 to the right of the column (thus, 2000 would become 20000, etc.)*

Z 2. TO ASCERTAIN THE MONEY VALUE OF RESULTING BUTTONS, FROM 160 AND 10 GRAIN ASSAYS, FOR GOLD OR SILVER, BY THE SUITABLY GRADUATED DIVERGING STRIPS OF THE PATENTED "EXPLORERS' TABLET GAUGE BUTTON VALUER."—Harkort, the celebrated Swedish chemist and blow-pipist, was the first to measure the very small buttons that were produced from blowpipe examinations for gold and silver. He *drew* two straight *diverging lines* on *ivory* or *paper;* the one divided into fifty equal parts, and the other into *loths' weight*, (as calculated by cubing the transverse line that lay under the diameter line of button), when placed with a forceps, under magnifying glass, to

* Here the real weights equal the numbered differences over A.

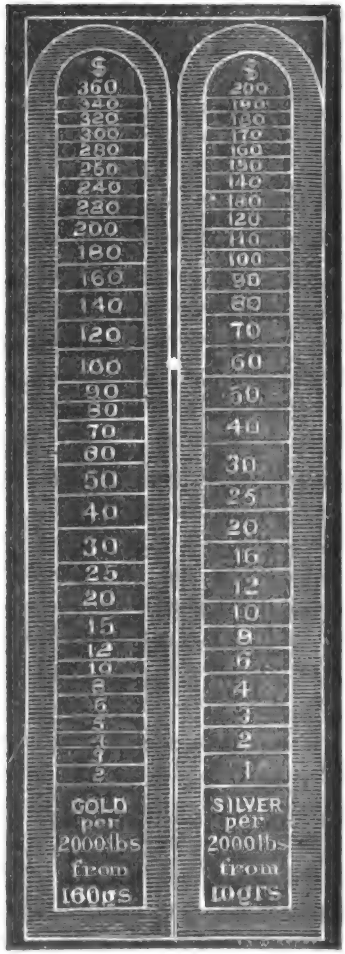
Cut 24.

Figure 1.



Calculating balance for thousandths' fine of bullion, percentage in base mineral assays, and for value of gold and silver buttons, from 160 and 10 grain assays.

Figure 2.



The Explorer's Tablet of the value of gold and silver globes, the resultants from samples of 160 grains for gold, and from 10 grains for silver; as measured by the suitably graduated diverging strips of the patented "Explorer's Assay-Button Valuer."

The Tablet is held at slight declivity, and the button is rolled down (one or more times, to obtain average), and stops as above at $110 of gold per ton of 2000 pounds, and $64 of silver.

exactly fill the intervening distance. He headed the left-hand column 50, and the right-hand column 143.62 loths *in weight*, recording the loths down, at every fifth part, to 0.14.

Plättner, in a subsequent work on the blow-pipe, gives these scales, and suggests another, as more suitable to the blow-pipe, headed 50 on the left, and 122.5 on the right; also *marked with loths* at every division (instead of at every fifth division of Harkort's), down to 0.0009. Both of these required great skill and care in *placing the button correctly;* and, although they were *theoretically* excellent measurers for weight, few men have pretended to realize much advantage therefrom in *practice;* whilst *neither* recorded the *direct money value at sight of gold or silver*, for blow-pipe or any other "assay ton," without further calculation.

In the patented "Explorer's *Tablet Gauge Valuer*," two *diverging and straight strips of metal*, being permanently secured on a bed, form *both guiding side fences*, as well as a *correct gauge of the diameters of buttons;* so that when a small globe of gold or silver, the product of the machine's assay, is dropped into the upper end of the gauge, it *naturally rolls down* to jam against *these sides*, the one of which is marked in dollars per ton for gold, and the other is marked in dollars per ton for silver, and read at sight, without any calculation, which can be rendered into pounds and florins by simply dividing these dollars by 5. It may be also used for one grain silver assays, by multiplying the figure opposite the button by 10. It will be thus seen that this is a practical instrument, which can be used for approximate purposes by any one who can simply read plain cash figures, and that it is not a merely theoretical toy, for exercising the *judgment* for its true position *over lines* (as seen under inaccurate divergent lines of vision), and governed by the subservient capabilities of the *hands and fingers*, to hold it correctly.

See illustration for manner of graduation (Cut 25, Fig. 2).

For alloys of gold and silver, see "Parting" of such, at the end of this chapter.

If the button from a *ten grain* assay with machine is found to be gold, multiply the dollars under the *balancing lever's* table by 16 for dollars of gold per ton, as this table agrees with a sample of 16 times as much, or 160 grains; also,

if 160 grain gold sample should produce silver, divide it by 16. So, also, when a button from a 10 grain assay for silver *produces gold*, the figure that is opposite the button, in the gold tablet, must be multiplied by 16; and divided by 16, if silver should be produced, instead of gold, from 160 grains.

16. THE ASSAYING OF GOLD BY MACHINE, IN ITS OWN INDEPENDENT WAY, AFTER WATER CONCENTRATION, BY FLUXED FUSION; READING THE DOLLARS PER TON AT SIGHT, ON THE SILVER TABLE, UNDER CALCULATING LEVER, OR BY TABLET.

Here the conformable quantity is taken for the machine "assay ton" for *gold*, so that the *calculating lever's table for silver*, as well as the tablet gauge, may value for both metals.

Fold a small business card along the middle, like note-paper for a paper scoop, which pass through the brass scoop-pan of main lever of calculating balance, and cut from the upper edge of this paper card until it balances the pointer at the other end with the line on the cross lever, as the 10 grain weight marked A did when balanced, previous to weighing the sample for the silver assay, with this difference, that the paper must remain in the pan. Take the round *brass bar* weight that lies in the middle of the weight box, and gently place it down in the groove on the long end of the main lever, so that its outer end may be exactly over, or straight with, the *transverse line*, over which the \$80 and \$200 figures stand, and shovel your well mixed and prepared sample into the paper scoop, until the pointer again stands opposite the line on the cross lever's point, and the card paper will hold about 160 grains, the requisite quantity for calculator, and sufficient for a gold assay.

Carefully concentrate this 160 grains, as directed in Chapter III; and after drying the heavy residue, and extracting the metallic iron from pestle and mortar, if such were used (by a magnet or magnetized pen-knife, if you have them), smelt, cupel, balance, and read for value, precisely as directed for the silver assay by machine. Judge of its fineness and value by color, or part by acids, as directed towards the end of this chapter; then re-smelt with a very small amount of lead, and cupel into a button, for final weighing. In this operation, it will be sometimes very efficacious to place a small piece of

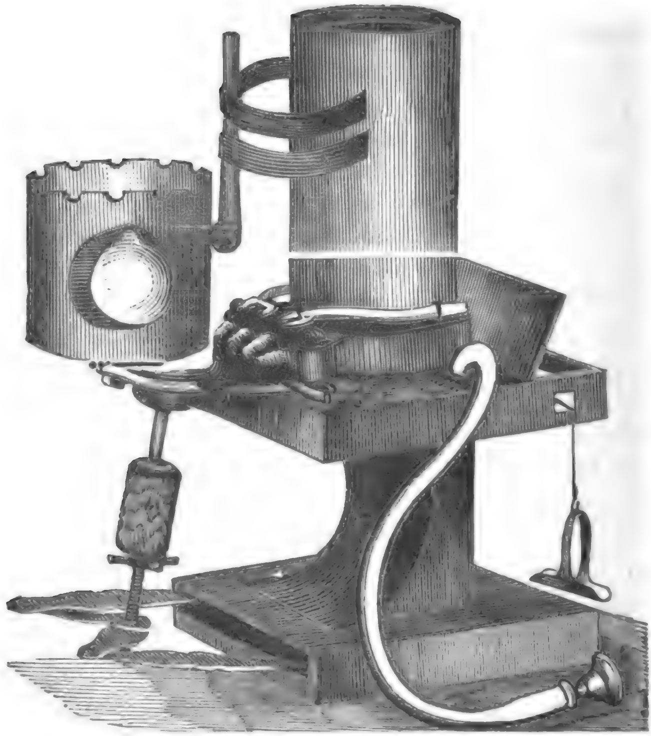
charcoal almost close over the button, as it lies in the cupel, to increase the heat and brighten up the alloy for cupellation.

In assaying free gold, that lies in clean quartz, where very little or no sulphurets are present, 10 times 160 grains may be taken (1600 grains), and, in reading the calculator, divide by 10 for value, by taking off one figure from the right-hand side of those under the button, which are headed by the same column or number as that on the weight.

17. ASSAYING OF GOLD SULPHURETS BY ROASTING, ACIDS, WATER, AND MACHINE.

Roast 160 grains in an old cup, crucible, or iron ladle, in

Cut 25.



(Fixed for Roasting, Fusion *at any required degree*, and Ignition.)

an open fire, with half its weight of powdered charcoal, at a red heat, gently stirring nearly the whole time with an iron wire, for from a half to one hour, until no sulphurous fumes

can be recognized, when it is removed from the fire, and pulverized in the same vessel, by rubbing. Carefully transfer the whole contents to a clean cup, saucer, basin, or dish; add thereto double its volume of pure hydro-chloric acid (muriatic), which does not dissolve gold, and boil in the chimney, or open air, for an hour.

Add water, pulverize, and pass off all the light floculent matter, sulphur, and the iron that is in the solution; smelt, and cupel the residue of gold, and read its value under lever, as if it were a 10 grain sample of silver ore. In this case, the roasting may be effectually performed by machine, either in the *transversely inserted* muffle-like crucible of clay or platinum (as shown by Cut 25), or the crucible may be placed in the burning charcoal of the cupola furnace, from above, and heated as required by the oil flames.

18. ASSAYING 100 GRAINS OF SILVER ORE BY ROASTING, ACID, AND MACHINE.

It may be sometimes desirable to assay a larger quantity than 10 grains of ore, which you can do as follows, in a very correct manner, even when chloride of silver is present, which, in its unroasted state, is insoluble in acids.

Weigh 100 grains of the properly prepared sample, which roast (for thirty minutes, at red heat, to decompose chloride that is insoluble in acids), with half its weight of pulverized charcoal (flour will do), in a cup or crucible, stirring it the whole time, with a long but small iron wire. If a crucible has been used for roasting, after it becomes cold, first pulverize by rubbing, transfer it to a porcelain cup, then add to the ore of either of these cups twice its volume of nitric acid, to which a thimbleful of *rain* or *snow water* has been added.

Boil the contents for one hour, and allow it a half-hour to get cold. Filter this liquor through blotting or filtering paper, into a clean bottle, and pour in about two tablespoonfuls of *rain* or *snow water* (because it contains no salt) above the residue, to wash through the remaining liquid, that, by still adhering to the sample, would retain silver.

If you have not a glass funnel, you can substitute it by inverting a small whisky bottle (first filled with sand), between

your knees, and suddenly striking a large nail through its externally concaved bottom, to form a suitably small hole.

To four tablespoonfuls of water, placed in another bottle or cup, add two teaspoonfuls of common salt, and, after it is dissolved, pour it into the assay solution very slowly, or drop by drop, taking notice if it renders it milky, or curdles white, by forming chloride of silver from the union of the chlorine of the soluble salt with the silver of the solution, if any silver is present therein. If there is no silver in solution, it will not become in the slightest degree milky, and the smelting and cupellation to button need not be performed; but, if it changes ever so little, you may proceed by adding the salt water until the liquor is not affected thereby. (If you give it all, *provided it is in solution*, although it is unnecessary, it will do no harm.)

Now by again filtering this liquor slowly through a small piece of blotting paper, the curds of chloride of silver will not pass through, but remain on the upper side of the filter.

If you wish a machine button, dry the filter at the boiling heat of water, fold up the paper to enclose the chloride, place this ball of paper in the charcoal support of the assaying machine, and on it 10 grains (one balancing) of borax glass, and 40 grains (four balancings) of test lead, and then gently increase the blast to smelt and cupel, as previously described for machine.

Of course, this button will balance over a figure that is ten times too high for the calculating lever's table, by the ordinary weights for the 10 grain assay, so that you must either strike off a figure from the right-hand side, or use the weights X 2, X 3, X 4, and then read the figures as they are on the calculator's columns.

19. ASSAYING OF SILVER WITHOUT ROASTING, BY AMMONIA, NITRIC ACID, AND SALT; THEN SMELTED AND CUPELLED BY MACHINE.

Where you have ammonia, nitric acid, and common salt, but no facility for roasting, take 100 grains of silver ore, that you suspect may contain some silver in chloride form, which is insoluble in acids, but completely soluble in ammonia. First dissolve what you can, by boiling in a bowl for an hour,

in about thrice its volume of watered nitric acid; allow it to get quite cold; then, after adding about a wineglassful of distilled, or rain, or snow water, filter the liquid through into another bowl. Next pass a second wineglass of water through the solid residue on the filter, to dilute and wash the *last traces of nitrate* of silver, etc., etc., into that already passed through. Precipitate this solution with salt, as in the last example. If mercury should be present, it would be also precipitated. Next lift this funnel off, that contains the remaining undissolved ore, and spread the filter in the bottom of another clean cup, which just cover with ammonia, and warm it for a quarter of an hour over a coffee-pot, half-filled with boiling water. Again filter this solution into another clean cup, well washing or squeezing the last relics of moisture from these first and last spongy filters and gangue, so as to obtain the whole of the silver.

Now precipitate the silver from this solution, by the *slow* addition of nitric acid (but not from the nitrate solution) into the *chloride* state; and, after carefully pouring off this liquid therefrom, to add a wineglassful of pure water; filter both the solutions on separate filters, and finish into button by machine, as before.

As ammonia precipitates many other minerals from nitric acid solutions, they should be treated separately *to the end*, as described.

20. HUMID ASSAY OF ALL KINDS OF SILVER ORES.

Weigh 100 grains, and otherwise manipulate according to either of the two preceding examples (the former will be found more reliable and convenient in the hands of amateurs), until you have precipitated all the silver by the salt or acid; then, having a superior balance and set of weights, you may remove the filter to a clean porcelain bowl, and dry it thoroughly by placing it, as a lid, over a sauce-pan, kettle, or coffee-pot, half-filled with boiling water, for at least one hour, or until it ceases to lose weight; then hold it in forceps, and burn the paper thoroughly by the application of a match, over a clean saucer, allowing the chloride residue to fall therein. Sweep this into the scale-pan, or balanced weighing-

cup, and record its weight. The weight of the well burned, extremely light residue of paper may be known by burning another similarly sized piece, when, by weighing its residue, the proper allowance may be made. But, if it is well performed, this will not be necessary for practical purposes.

Another, and perhaps more satisfactory mode, will be to dry perfectly, at boiling heat, two exactly similar filters, and carefully balance them in the scale-pans, by cutting chips from one or the other with scissors.

Filter the solution through the one, and dry both as before; then the difference of their weight will be equal to the quantity of chloride of silver that is present. Or you can first *dry the one filter*, and either exactly balance it, if you are going to finish the assay right through, or take its correct weight, and, after the filtered precipitate has been thoroughly dried, to weigh it, and deduct the weight of filter for the actual weight of the chloride of silver.

It may be here particularly noted that the ore should be free from salt, and that, as mercury is also precipitated by salt to an insoluble chloride, its absence from the ore should be established before the last ammonia method should be relied on. If it should be present, it may be discriminated and allowed for as follows, after your filter has been weighed for chloride of silver, as above.

Place the dried, but unburned, filter in a clean basin, and pour more than sufficient ammonia thereon to dissolve the chloride of silver, and gently warm it over boiling water. If mercury chloride was also on the filter, it will not be dissolved, but blackened in color. Pour off the liquor, and, after it has been well washed and dried, it can be again weighed as before, when it will first show the quantity of mercury, and this being deducted from the supposed weight of chloride of silver previously obtained, will give the real weight of chloride of silver. So that it is self-evident to you that where there is the least chance of mercury or salt being present in any form—nearly always so in tailings, but seldom in ore—the preliminary roasting and final smelting and cupelling operations are to be preferred; for the former volatilizes the otherwise dangerous mercury, whilst the latter passes off all spurious matter, and shows you a tangible sil-

ver button, than which, following the chloride as it does, nothing can be more satisfactory.

The chloride thus obtained contains 75.3 per cent. of silver; so that, by referring back for your corresponding assay unit to the quantity taken for assay, you can readily calculate as before, after knowing the actual weight, in such units, of silver obtained. Thus, if 100 of chloride gives 75.3 of silver, how much will *your weight* (say 1.2) of chloride yield of silver?

Or 75.3 multiplied by 1.2 = 90.36, which, divided by 100, will give .9036 of assay unit.

Or 74.3 x 1.2 = 90.36, and, by moving two points to the left, is divided by 100; thus, 90.36 becomes .9036.

Or move the multiplier two to the left; thus, instead of 75.3, say .753 x 1.2 = .9036, as before.

Or weight 1.2 x 3, and divided by 4 = .9, will be sufficiently near for most purposes, as it varies in this case but thirty-six ten-thousandths of $37.71, or but thirteen cents per 2000 pounds ton.

21. ASSAYING OF SILVER BY SOLUTION OF COMMON SALT, CALLED "VOLUMETRIC."

This method was first devised by Guy Lussac, and, although it is very suitable for the purposes of experts, with laboratory facilities, who have many assays to work through every day, most of which may be bullion, it is certainly not so subservient for the occasional and more diversified practical purposes of the miner, millman, or smelter; and therefore it has been seldom used for superior facilities over other methods.

In common with all the peculiarly acid methods, where salt is the precipitant, the lode or its mineral should contain neither *salt* nor *mercury;* for the former would precipitate the nitrate of silver to an insoluble chloride as soon as formed, so that the filtered solution would be robbed of this much by its lying on the upper side of filter; whilst the latter, as soon as the test salt was applied, by rendering the filtered solution milky, from the nitrate of mercury being thus changed to chloride, would deceive the best judge, by creating a similar appearance, as well as using a larger volume of the test solution than belonged to silver.

It may, however, be correctly accomplished on all ores, after efficient roasting, by dissolving and filtering to a clear solution, as directed under No. 18; but, instead of precipitating and weighing as described under No. 20, for the simple humid assay of silver, it is placed in a clear glass vessel, as a Florence flask, and the quantity of silver is ascertained by visual notice of the milkiness produced by certain volumes of a previously regulated salt solution. This solution, thus dissolved in nitric acid, is then changed, by the addition of a highly diluted, clear and correct standard solution of common salt, to a chloride, which renders the silver liquid, more or less milky, and slowly precipitates it to the bottom of the vessel, when more salt solution may be then added to test the upper and clear solution, until the exact time has arrived when no milkiness is produced thereby. The measured volume of solution used corresponds with, and informs you of, the quantity of silver present in the sample by any "*assay ton*" *quantity* you may desire, as described for other methods.

For metallurgical works and mints, where large quantities of silver have to be otherwise treated in the wet way; it is frequently advisable to assay by this means, where it will be better to prepare the solution of salt in such a manner and of such strength that every 100 grains or volumes of the solution shall precipitate one grain of pure silver; and, to prepare such a solution, it will be necessary to add to every 99.4573 parts, by weight, of pure water, 0.5427 parts of pure salt, and to check and perfect to accuracy by subsequent trial on pure silver, with the graduated tube for this method of assay. This parallel and cylindrical glass tube, of about fourteen inches long and one-fourth of an inch internal diameter, is graduated, for about nine inches in length, into one hundred parts, for reading equal volumes, the termini of graduations stopping somewhat short of each end. To facilitate its being filled and emptied as required, the bottom is somewhat contracted to a dropping point, so that, by applying the thumb to the top end, the liquid may be closely regulated, retarded, or stopped, by necessary admission or stoppage of the air, as and when required during the test for quantity of silver in solution. Each mark will, of course,

then represent one-hundreth of a grain of silver precipitated. Stronger or weaker solutions may be made, to suit any desired "assay ton," or for *hastening the work* during the first part, in assaying rich bullion.

These solutions will require frequent corrections for strength, as well as for the temperature, and consequent change of bulk; and as I do not deem it sufficiently important for the readers' purpose to use some sixty pages for its full explanation, tables, etc., I must refer the very few who will require more information on the subject to John Mitchell's work on Assaying, where he has translated the whole *modus operandi*, etc., etc., from the French description by Gay Lussac, the inventor of the process.

For my occasional mineral purposes, both for tuition and use, I have found it more convenient to approach accuracy in the solution, and to calculate for value as follows. Weigh out the last named ratios of ordinary filtered water and common commercial salt, and add a slight excess of salt (or, in fact, any other ratio within practical limits); then dissolve one grain of pure silver in nitric acid, and very carefully ascertain how many units of the one hundred parts of the graduated tube, it requires of the solution, to precipitate the one grain of silver; which, for illustration, we will suppose to be 98.

This may be then used as a base for calculation; thus, if 98 volumes precipitate one grain of silver, how much will the number of units required for your assay solution precipitate?—and you obtain the answer, in grains; which will lead to any other answer required, by further calculation in the ordinary way for ounces or dollars per ton.

Here you may also simplify the mode, and come to direct answer, by taking any other silver button from assay of known *ton value;* dissolve it in nitric acid, and precipitate as you did the one grain above. Thus, supposing the dissolved button obtained from any assay ton represented $75 per ton, which required say 65 volumes of solution of salt for precipitation, it would again be: as 65 volumes are to $75, so are the volumes or units required for present assay, to its dollars per ton.

Or, as in the self-calculating systems, you may, by much

patience and perseverance, so strengthen or dilute your salt solution, that each *unit*, being equivalent to "*assay pound*," may represent $1 in value for a suitable "*assay ton*," as fully explained in the self-calculating arrangements in the fourth part of this chapter.

22. ASSAYING OF GOLD BY "AQUA REGIA."

Gold can be assayed in the wet way, by dissolving say one part of the pulverized sample, placed in a glass flask, bowl, or cup, in two parts of what has been called "aqua regia," which is a varying mixture of from two to four parts of hydro-chloric (muriatic) acid with one part of nitric acid; the former being varied, for the better solubility of the associated base minerals; it may remain for about two hours in cold solution, but one hour will suffice if it is kept gently boiling. It must be now diluted with its bulk of water, then filtered through the regular filtering paper (or common blotting paper, first soaked in clean water, will answer in its absence) and evaporated over a lamp, as described under the twenty-fourth heading, on "Parting," etc., to perfect dryness. Water must now be added to this dried residue, for the purpose of re-dissolving the chloride of gold that has been thus formed (by the chlorine from the hydro-chloric acid), and which is completely soluble in water. Lastly, boil this solution, with either sulphate of iron in saturated solution, or with oxalic acid, until all the gold is precipitated as a brown powder, which can be well washed, dried, and weighed, in the manner described under the twenty-fourth heading, on "Parting Gold from Silver," and calculated as under the third heading.

There are many precipitants of gold, but these will be best for your purpose. Oxalic acid may be made, when required, by dissolving one part of sugar in six parts of nitric acid, boiling the solution until the reddish fumes cease, and taking out the *crystals of oxalic acid when the liquor is cold.*

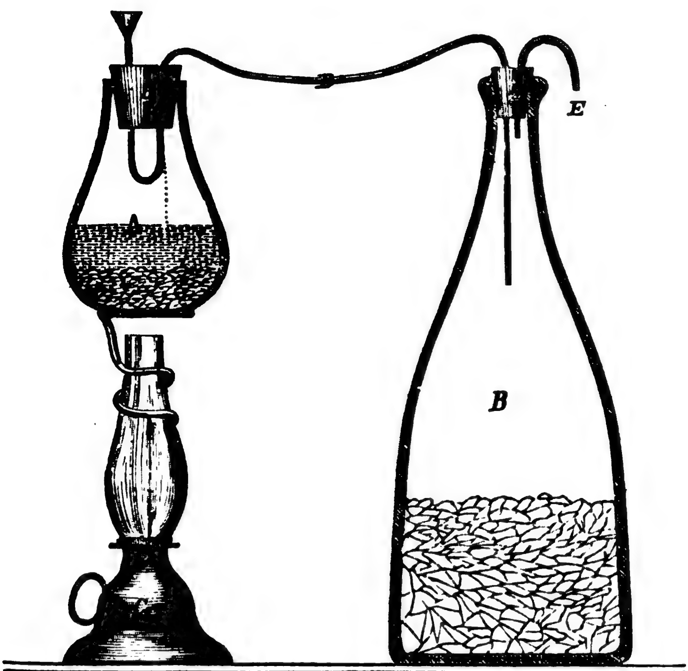
23. ASSAYING OF GOLD BY CHLORINE GAS.

A. Auriferous quartz and sulphurets of iron may be assayed, and experimented on for ascertaining the percentage

that can be obtained from the ore on the large scale, by being dissolved in chlorine water that has been chloridated by chlorine gas, and precipitated by sulphate of iron, in miniature apparatus (sold by Messrs. John Taylor & Co., of San Francisco), which exactly resembles in action that for the Plattner's process in the manipulation of roasted sulphurets on the large scale, which will be fully explained in the last section of this book.

B. *For itinerant purposes, I would suggest the following extemporized means for assay and experiment, which can be performed with much greater ease and facility, and is even more correct and exacting.*

Cut 26.



Take a large-mouthed pickle jar as that shown by A, Cut 26, and a large demijohn, small-necked glass or stone bottle, as B, or other suitable vessels (which will hold sufficient for the quantity on which you would wish to assay or experiment), and the common naphtha lamp, C, Cut 26, to warm the solvent.

A cork cover must be shaped to suit the large-mouthed stone pickle jar, and two india-rubber tubes obtained, the one about three feet six inches, and the other six inches long, and from one-fourth to three-eighths of an inch internal diameter, to feed the acid and form the connections as shown, for conveying the chlorine gas, as generated in A, into B.

Now, two, smooth round holes must be made in A's cover, and two more in the cork of B, just so large as is required to make a gas-tight joint by mere compression on the rubber tubes.

To afford safety, and at the same time obtain the necessary pressure for urging the gas forward from A to B, as well as for providing a kind of "stink trap" to prevent the otherwise direct ascent of the gas, the rubber tube should be looped in the manner shown under the first, or A's cork, and on the right or ascending side, at about two inches above the bottom of loop, and say one inch under the wood cover, a hole, one-fourth of an inch wide, and a half-inch long, must be cut, to allow the acid to pass in from the first or short end, and at the same time give free passage for the gas from A into B, through the long end; whilst all goes well, all backward passage is thus prevented, without the use of glass fixings.

The other end of this pipe, D, may descend into B about five inches; whilst the short tube, E, merely starts just under the cork, for the conveyance of the lighter air away as the heavy gas enters on the ore.

The apparatus being made as above, take twenty pounds of pulverized quartz, or sulphurets of iron; the latter must be well roasted and stirred at a red heat (with about a teacupful of finely powdered charcoal, if you have it), for at least two hours, in an old wrought-iron frying-pan, and allowed to become quite cold. This must be placed in the large demijohn, B, and gradually moistened with water throughout, by frequent small additions and shakings, until it becomes of just the consistency of *mason's mortar for trowelling*, when you may force in the cork, *b*, to stop the mouth of the demijohn. Now place four ounces of finely pulverized *peroxide* of manganese in the jar, A, which securely stop with the cork, *a;* and mix sixteen ounces of hydro-chloric (muriatic) acid with eight ounces of clear water, and pour this into

the vessel, A, eight ounces at a time, at intervals of about thirty minutes. The chlorine gas thus formed, over a gentle heat from the lamp, C, is pure, and can be passed over through the rubber tube, on to the ore, and, being much heavier than air, will lay down thereon, saturate its water, and dissolve the gold. Before *re-supplying the acid*, the large bottle, B, must be well shaken each time, which can be done best after removing the cork, *b*, and substituting a separate cork for this express purpose.*

It can be done, however, without this, by stopping the rubber tubes, either by compressing them in a cloven-ended small branch of a tree, similar to a clothes' pin, or by tying them with a cord, during the time required for shaking.

C. Another, still more convenient, and very easily applied method, is shown by the following illustration.

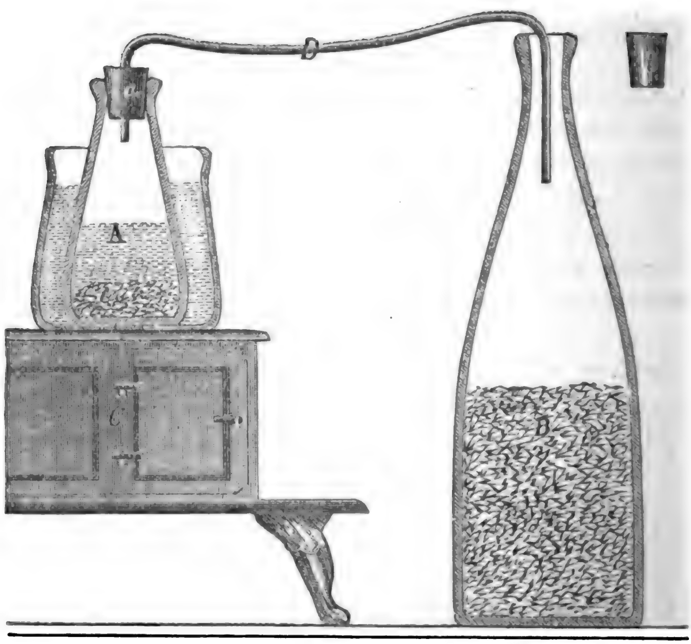
The bottle, A, is put into a saucepanful of cold water, and after being placed on a stove, or over any gentle fire, the bottle, A, is first supplied with *all* of the dilute hydro-chloric acid and peroxide of manganese, as given in the last example, under heading B; then corked by *a*, which has now but one hole, to receive a half-inch (internal diameter) exhaling rubber tube, which need not be more than about eighteen inches long, to carry the gas into the *open-mouthed demijohn* or jar: as the water gradually warms, the heavy chlorine gas passes through and falls down on the moistened ore, until the bottle becomes nearly filled therewith, which may be seen by its yellow color. The rubber tube may now be stopped for a moment, and the *whole gas-forming and supplying part removed out-doors*, or the tube passed down into another small-necked bottle for a few minutes; whilst the demijohn that contains the chlorine and moist ore is closely secured by cork *b*, and violently shaken for some minutes, to more thoroughly chloridize the water for dissolving the gold; the demijohn is again placed in position, and supplied, as before, with more gas, for another more lengthened repetition of this

* This is a better and easier way for obtaining the chlorine gas, for assaying purposes, than the mode practiced on the large scale, where about eight parts of sulphuric acid, acts on a mixture of five parts of water, four parts of salt (chloride of sodium), and three parts of peroxide of manganese.

shaking process, when it may be allowed to remain over night, thus securely corked.

In the morning, pour in about one quart of water, and shake, as before, to absorb the remaining chlorine gas into solution; allow it to stand for an hour; then nearly fill the vessel with *warm water*, and, after it has had time to settle, carefully pour the liquid off into a clean earthenware or glass vessel (filtering it is much better, if you have facilities); then, after pouring in a second quantity of about two quarts

Cut 27.



of warm water, to extract the remainder that still adheres to the residue of sample, the gold may be precipitated by solution of sulphate of iron or oxalic acid (made as described under heading 22), as follows.

About twenty drops of hydro-chloric (muriatic) acid is now added to the clear liquor, and some dissolved sulphate of iron, or oxalic acid, which must be occasionally stirred with a glass rod (or a small inverted glass bottle, test tube, or slender piece of wood), until all the gold has been precipitated.

The liquor should be then filtered; the filter dried in a basin, at 212°, over a sauce-pan of boiling water; then flamed and burned to powder in this basin, and the gold separated by water-washing, and subsequent drying, as previously described at pages 129 and 152, under heading 12 of this chapter.

The filtering may be dispensed with, if you lack such convenience, or knowledge, by pouring the liquor carefully away, cleaning and drying the gold after the manner under heading 12, and weighing it for value by the mode described under the "Parting of Gold from Silver," under the twenty-fourth heading of this chapter.

Or the gold and dirt can be cupelled with lead, if you have a furnace or *machine.*

To calculate the value per ton for a twenty pounds' sample, multiply this weight of gold obtained by 100, for what a 2000 pounds' ton of such will produce.

For any other quantity, see the third and fourth headings of this chapter.

Chlorine gas is not only disagreeably pungent, but very poisonous, when inhaled; so that it must not be allowed to escape into the room in any quantity.

24. PARTING OF GOLD FROM SILVER AND BASE METALS.

In the separation of gold from silver and the base metals, the following *five hints should never be neglected.*

1. The alloy must not contain more than one-fourth of its weight of gold; if it does (*which may be known by not being blackened by the nitric acid*), sufficient silver must be smelted into the alloy, before the acid will thoroughly dissolve out the desired metals, and free the pure gold.

2. The nitric acid must be free from hydro-chloric acid, and have about a certain specific gravity, of 1.16 for large operations, by dilution with a proper quantity of water.*

* For the ordinary purposes of assaying, such as parting the resultant buttons, it will be quite unnecessary to observe this extreme nicety in the strength of the acid; for it will be seen that if a little too much water should be first used, it will evaporate quickly off, so that this exact strength is merely nominal, and can be retained but for a second of time, as continued evaporation will soon pass *all* off, and rectify the acid. Therefore, about one part of water to four parts of the acid will suffice for such occasional purposes.

3. The button must be flattened very thin, and boiled therein for from five minutes to twenty minutes or more, according to its size, for some time after all action ceases.

4. The residual brown gold must be well washed, in either distilled, snow, rain, or, at worst, comparatively pure water, which must be more particularly free from salt, that would increase the weight of the supposed gold, by depositing a coating of chloride of silver on its surface.

5. It should be warmed to red heat, until the brown metal shows a golden color, for more positive proof of its purity, and the total absence of all other substances that might have adhered thereto.

For bullion assays, where a large metallic sample is chipped off from the brick to ascertain its thousandths fine for silver and gold, the base metals' thousandths are first oxidized away in the air and cupel, as in previous examples, which leaves the pure alloy of silver and gold: these are usually parted by assayers as follows.

The total weight of the refined alloy is first ascertained; the button is then hammered—or, better, rolled—very thin, and coiled into a more compact cylindrical shape; it is next placed into the bulb of a glass parting flask, which has the size and shape of a hen's egg, but prolonged at its smaller end, for about eight inches, by a half-inch tube, which serves to partially condense the fumes from the acid; and it holds sufficient water to cleanse the parted gold and convey it to a small crucible, for being warmed to redness in the muffle of the furnace, which must be kept hot for the purpose.

In mints, and the large bullion establishments of cities, several of these flasks are used together, and, after the rolled and coiled samples are placed in these vessels, the egg-shaped bulbs are half-filled with acid of 1.16 specific gravity; they are then placed in a suitable rack, and somewhat reclined position, over as many gas-burners, to be gently boiled for from twenty to thirty minutes, so as to ensure complete solution of all the silver.

The flask must be filled with *pure* water, then carefully decanted, and re-filled. Now, with the left hand, place the smallest sized French crucible over the mouth of the flask, and with the right hand gently invert the latter, so that its

water may quietly pass away, whilst the gold drops and remains in the crucible. A little practice will be necessary to perform this with ease and certainty.

Being sure that all the gold has descended, you may now remove the flask, and, after pouring the remaining water away from the gold, place the crucible first in the mouth of the muffle, for slow evaporation of its moisture, and thence into the interior, so that the heat may be increased to redness, for purification, etc.

It must be then removed, and, after it becomes quite cold weighed for its thousandth's fine, and deducted from the total weight for the thousandth's of silver.

I have used, when away from gas, the cabinet described under the ninth heading of this chapter, where the bottom front row of pigeon-holes were marked from A 1 to 10, for weighed assay; the second front row, marked B 1 to 10, received the resultant crude *button*, from smelting; the third front row, marked C 1 to 10, received the *cupelled* button; and the top row of the cabinet, marked D, received the *deposit* of gold, after it had been parted, in such flasks, that reclined against their respective numbers, over as many small lamps, which had been supplied with sufficient alcohol to burn the proper maximum time of thirty minutes.

I have at other times rendered a common naphtha household lamp most subservient for such purposes, by entwining a small wire around the upper part of its glass chimney which terminated in a ring to support the dish; as C, under vessel A, Cut 26.

For quartz assays, and other isolated, occasional requirements of miners and metallurgists, the following will be more available and convenient, and, for such small quantities, much more exact, than the method described. Take, instead of this flask, a small porcelain dish, a thin tea-cup, or other similar *open* vessel, that will stand the actions of acid and the necessary heat, and boil the button therein for from ten to twenty minutes, according to its size, until all the silver is dissolved. This may be done over a clean heated stone, a hot stove top, or, still better, on the ring of wire over the household naphtha lamp, as described; which is smokeless, and superlatively convenient for such and similar purposes,

as the heat can be suitably adjusted and equally sustained to suit your various requirements, by the wick-elevating side screw (as seen in front of lamp C, Cut 26).

This being accomplished, the acid may be poured away, and the vessel carefully filled and emptied with clean water twice or thrice, when the brown deposit of gold may be boiled in the half-filled vessel of water, for a few minutes, to remove any adhesive foreign substances ; and then, after this water has been very carefully poured away, the dish and gold must be warmed as hot as possible, until you are satisfied, by its appearance through a magnifying glass, that nothing but gold remains. It will not attain general gold-like lustre at this temperature—only a partial but satisfactory color; which will, when bruised, expose the bright gold yellow.

With the glass in the left hand, and a sharp-pointed pen-knife or forceps in the right hand, you may now loosen any one of these sponges of gold that adheres to the dish, or cup, being careful that if any particle thereof sticks to the knife or forceps, it must be returned by a gentle tap on the edge of the vessel.

When this becomes *quite cold*, it may be weighed to the most exact degree of nicety that is possible for your balance to realize, in the following manner.

Cut two similar pieces of thin unglazed or common blotting paper, about one and a quarter inch long by one inch wide, and after folding them the *long way*, like a sheet of note-paper, trim off the corners with scissors, so that they may exactly balance on your scales. This supple, steady, compliant, and retaining bulbous paper is much more suitable for such purposes, than the rigidly elastic, wild, uncertain motioned, and slippery, glazed note-paper.

Now, these being balanced and *suitably folded*, you can remove the one from the pan, to a clean dry spot, in front of yourself and scales, and, by taking the vessel that contains the gold in the left hand, you can so incline it, that, assisted by gentle taps with the pen-knife or forceps, every particle of gold will fall on the flat half, of the folded balanced paper, whilst the nearer half will form a vertical and most effectual stop-fence for the gold, and a convenient handle for replacing it in the scale-pan, for ascertaining its weight.

25. PARTING, BY EXTRACTION OF THE SILVER FROM A FLUID ALLOY OF GOLD AND SILVER, BY CHLORINE GAS.

The affinity of silver for chlorine is much increased by high temperature, whilst gold almost loses its affinity, and is therefore indifferent under such conditions.

These properties have been long known, and acted on in many modified ways for preparatory roasting and simultaneous chloridation of silver ores, to render them less refractory, for the various subsequent methods, for manipulation by pan amalgamation, smelting, or purely chemical treatments.

Plattner's process for extracting gold from previously roasted sulphuret of iron depends on the fact that cold chlorine water has such a strong affinity for gold that it can be readily dissolved therein, and again precipitated at pleasure, by sulphate of iron, etc., etc.

Mr. Miller, of Australia, the Assayer of the Sidney Mint, knowing of this indifference of hot or molten gold for chlorine, has recently experimented thereon at that establishment with apparent success, for refinage of their gold for coining purposes. As it is irrelevant to your requirements, I speak of it more as an interesting and novel application in large metallurgical works, rather than for its appliance in your business.

I see, from the inventor's lengthy description of the mode of operation, published in the *Chemical News*, that it is accomplished as follows.

One or more (of 17 or 18 sized) French crucibles are duly prepared with borax, and laid in the cold furnace, to be slowly and carefully heated to dull redness, when from 700 to 800 ounces of the auriferous alloy (cast in such a shape that two ingots shall suit the crucibles) are placed in each crucible, and quickly melted; from two to three ounces of fluid borax is now poured from another hot crucible thereon.

During the last ten minutes of this melting, a small fire-resisting clay tube, that forms the nozzle or fire-end of the chlorine-supplying pipe, has been slowly heated, so that it may not split when introduced into the melted gold. This pipe is now carefully lowered to the bottom of the crucible, which must be now covered, and at the same time supplied

with chlorine gas, to prevent the gold from rising and settling in the tube.

Being kept in this position by a few small weights, it is continuously supplied, by suitable pressure, with the gas, which quietly bubbles up through the molten alloy, and projects no globules of metal away.

Variously colored fumes arise during the process, which indicate the presence and exit of the different oxides or chlorides of the base metals, and when these have all passed, and all of the silver has been chloridized, the chlorine gas shows its characteristic yellow, and deposits this color on the stem of a white clay tobacco-pipe, when inserted through a hole in the crucible-lid, a plug being removed for that purpose, the operation (which requires about one hour and a half) is now suspended, the crucible removed from the fire, and the liquid chloride of silver poured into suitable dry moulds. After its solidification, the red-hot gold is extracted, by inversion of the crucible, and thrown into a concentrated boiling solution of common salt, which dissolves the adhering chloride of silver. It is said that all these operations can be readily performed, and about 2000 ounces refined in three common melting furnaces, in five hours; and that the thousandths and quantity of gold then retained equal that from other methods.

26. PARTING OF GOLD, SILVER, AND BASE METALS, WHEN AMALGAMATED WITH MERCURY.

The dry amalgam, as received from the strainer, or buckskin, when in considerable quantity, is first freed from the mercury by being retorted over a fire; the mercury is recovered by condensation, whilst the gold and silver, alloyed with the base metals, remain as metallic sponge; which may be fused in a crucible with borax, and cupelled in sufficiently large concavities of bone ash, with a suitable amount of lead for proper purification, as described for cupellation on the small scale. The base metals can also be oxidized away by adding sufficient nitre to the borax, during fusion in crucible; and the alloy of gold and silver poured directly into moulds.

The silver and gold may be then assayed for thousandths

fine of each, by either drilling a hole through the brick, or chipping off a sufficient quantity from the corners—say 10 or 100 grains—for separation by acid, etc., as under heading 24.

Small balls of well compressed amalgam may be wrapped in strong folds of paper or rag, with half their weight of borax; then gradually heated and fused in a somewhat capacious crucible, with sufficient lead, and cupelled; or, being first correctly fused with borax and nitre, after the base minerals are thus oxidized, they may be more directly parted by nitric acid, without cupellation, as before, for thousandths fine and value.

27. REFINING OF GOLD AND SILVER FROM ALL SOURCES.

The refinement and separation of gold and silver, although a strictly metallurgical operation, is not always accomplished in the most direct chemical manner, but is varied to suit commercial circumstances; and such re-agents are used for dissolving and precipitating the silver as will best answer the two purposes of obtaining the silver, and the resulting profits from the sale of the more suitable simultaneous productions.

These more varied modes need not be exposed here, as the miner will not require them.

The most effective method for refining gold and silver is that so graphically described in the Bible; the base minerals were then oxidized, as they now are, by cupellation on a porous support, at suitable temperature before blast; the only difference being in the superior mechanical arrangements of modern times.

As the cupellation of large quantities of base bullion, for its silver and gold, must be illustrated and fully described in Chapter IV of Section V, on Metallurgy, we will now but consider the more simple and ready methods for the melting and cupellation of the smaller quantities that are generally required by miners, after the more ordinary milling operations, rather than those from smelting, etc.

These small amounts of gold or silver, when either separate or alloyed with each other, and with the base metals, may be treated in the following manner.

A. A crucible of good sound clay, or plumbago and clay composition, is selected, of suitable capacity for conveniently

holding the required quantity of alloy; and placed in the furnace, in such a position that it can be enclosed with a sufficient amount of charcoal or coke to produce the intense heat, that must be now gradually attained, for the proper fusion and refinement of gold.

If the mass of alloy is comparatively pure, it may be immediately refined in the crucible, by first adding thereto about from one to four per cent of nitre (nitrate of potassa), then from one to five per cent of borax, and, after it has become thoroughly fluid, some finely pulverized bone ash should be thrown on its surface. The nitre oxidizes the base metals; the borax, by forming fusible slag with the gangue, iron, etc., will extract and bring such to the surface of the molten metal; whilst the bone ash, being thrown on a few minutes before pouring into the ingot mould, will absorb the base oxides with the uncombined surplus borax and slag, and otherwise serve to clean the metal, and complete the refinement to gold or silver.

B. A large clay crucible, that has been previously used for smelting (if cracked, it will answer this purpose) may be rammed with bone ash, and suitably concaved to retain the alloy. This prepared cupel must be gradually dried, then placed in the furnace and warmed to bright red, when the alloy is put thereon, with sufficient lead to extract the base minerals, by oxidation, which pass away both in fumes and into the bone ash, when the *air is allowed to enter freely over the molten metal,* from the top of the furnace.

The quantity of lead will vary from about one-fourth to ten parts, according to how much the alloy contains of the base metals to be thus oxidized; which should be approximated by a preliminary examination with blow-pipe, or some other method. The appearance of the insufficiently refined fluid metal will also inform you when more lead should or should not be added; which see, under heading 2, Cupellation.

C. Large sized scorifiers will be found very convenient and effective for the refinement of ordinary quantities of gold, for they can be thus shaped with bone ash, and the refinement performed in the muffle.

If one is of insufficient capacity, the bullion may be

divided, and as many as eight scorifiers can be worked at once, by the double muffle arrangement of the furnace, as illustrated at page 229. (Old scorifiers will do.)

The bullion, being thus refined by fluxed fusion, or by cupellation, must be parted by one of the many humid methods, and the two following will be found most suitable for your general purposes.

D. Separation of Gold from Silver for Realization.—These operations, that have been so much varied at different places, to suit especial commercial circumstances, as to the prices of re-agents and sale of resultant products, may be performed by you, in two ways, as follows.

1. Dissolve the alloy of gold and silver (which must contain, for reasons stated at page 279, under heading 24, at least three parts of silver to one of gold), in a suitable vessel, with boiling nitric acid of 1.16 specific gravity, until the sponges or flocks of gold are perfectly freed from silver; then transfer the solid residue of gold, or the nitrate of silver solution, into another vessel, for the more complete purification of the gold by water-washing, and subsequent fusion, for the purpose of its being cast into an ingot; whilst the silver is precipitated as a chloride by common salt, from the solution, which may be fluxed after the manner suggested by Gay Lussac, and used by Dr. Miller: that of mixing to every 100 parts of the chloride, 70.4 parts of carbonate of lime (say chalk, marble, or calc), and 4.2 parts of charcoal. It must be warmed to dull redness, and kept so for a half-hour; then the temperature is increased to full red, which produces a mass of pure silver.

Gmelin advises to flux with one part of resin to three parts of the dried chloride, which are intimately mixed and packed into a crucible, to half fill it. A moderate heat is first applied, which gradually burns the resin; the heat is then raised to white red, when, the cover being first removed, a little borax is added, the contents are heated to more perfect fluidity, and the crucible removed from the fire. The masses of silver produced may be again fused with borax, and poured into moulds of any desired shape.

E. The alloy may be dissolved in boiling sulphuric acid, and the silver precipitated by metallic copper, in a metallic

state; whilst the copper, being thus brought into the solution as sulphate, will also become valuable to you, or can be sold in local markets. The metallic gold and silver can be collected, fluxed, smelted in crucible, and run into moulds, as before.

G. H. Makins, an assayer in the Bank of England, has described, in his Manual of Metallurgy, the following method for producing pure silver and gold, which may sometimes suit the more extensive requirements of the miller.

"To prepare it, coarse silver is dissolved in nitric acid, somewhat dilute; when all is dissolved but associated gold, a further quantity of hot water is added, and the whole allowed to stand until the gold has completely subsided; the nitrate of silver is then to be poured off carefully, and an excess of common salt added so as to precipitate all the silver as chloride. After subsidence, the acid liquid is decanted, and the chloride well washed with repeated quantities of hot distilled water, until the latter is free from acid. The chloride is then acidulated with hydro-chloric acid, added in the proportion of about one pint to each ten pounds of chloride. Into this mud a number of plates of clean wrought iron are put. A copious evolution of hydrogen is at once set up at the surface of the iron, and the solution of the latter commencing, the chloride of silver adjacent to the slips is reduced, and this reduction will spread from each slip of iron throughout the whole, which will thus become a spongy mass of silver. The silver should not be disturbed till all is reduced, or portions of chloride are apt to escape reduction. When all traces of chloride are gone, the iron is carefully removed, the chloride of iron solution poured off, and the whole mass covered with a quantity of hot water, to which about one-tenth its bulk of pure hydro-chloric acid is added. After standing a few minutes, this is poured off and renewed; and, after the decanting of the second portion, pure hot water is added; and, lastly, the whole is washed as quickly as possible with repeated quantities of hot water, until the washings will not render a dilute solution of ferrocyanide of potassium in the smallest degree blue. The silver is then squeezed by the hands, and dried in a porcelain basin. If this process be carefully carried out, it will give a product as fine as 999.7 parts in 1000; that is to say, containing only three-ten-thousandths of admixture, which latter is probably due to peroxide of iron."

CHAPTER VIII.

ASSAYING OF LEAD.

1. BY CRUCIBLE.—The ores of lead can be assayed for percentage of metal more promptly than those of gold and silver; but great care must be taken to understand the constitution of the mineral, if accuracy is essential; unless this deficiency of knowledge for exact fluxation is rendered unnecessary, by relying on the universal action of, and chemical changes produced by fire, during a preliminary roasting at a *low red heat*, when *stirred for some twenty minutes.*

All lead ores, that are valuable to the miner as such, when thus roasted, as well as those several *unroasted* ores of carbonate, chromate, phosphate, and oxide of lead, may be fluxed and smelted in the following manner.

A. Average your sample with great care; take 25 grains of ore, which project, by a long-handled scoop, into your red-hot crucible; then, after quickly covering this with 100 grains of carbonate of soda, close the furnace for from fifteen to twenty minutes, when you may remove the crucible from the fire, tap it lightly, to precipitate and unite the molten globules of lead, and, when the crucible becomes quite cold, it may be broken, and, after the button has been brushed clean and weighed, the ore's percentage may be known by multiplying this weight by 4 (or, 100 grains may be taken).

This will extract as much lead (when properly conducted) from all classes of ores, as any other mode; and, even when sulphuret of antimony is also present, the latter will not be reduced by these fluxes, but will volatilize, and combine to form slag.

For ordinary purposes, even the worst ore, that of sulphuret of lead (galena), and antimony, need not be roasted.

The sulphuret of antimony is often associated with that of lead, in the Pacific slope States and Territories of North America; and, when it is present, this mode will be found (for the reason stated) all-sufficient.

When antimony is present, an iron crucible must not be used, as it also *reduces the sulphuret of antimony to metal.*

B. Should it be required to ascertain, also, the percentage of antimony, the *same quantity of ore may be treated as above for lead;* but, for both lead and antimony: to this end, the 25 grains of ore must be fused with an intimate mixture of 75 grains of carbonate of soda, and 75 grains of cyanide of potassium, which will reduce both metals; and this weight, multiplied by 4, will give the percentage of alloy, whilst, the former percentage of lead being deducted therefrom, the difference will give the weight of antimony.

The purity of lead is best ascertained by flattening the button to a very thin disk, so that its edge may be characterized by absence of cracks, and for its ductility and tenacity; whilst the middle may be still bent repeatedly without fracture.

The above modes are universal and reliable for all the ores of lead which are of any value to the miner.

There are several other methods practiced in different districts for assaying pure galena; but they require *much discretion*, where there is any chance for *associations of antimony, etc.*, or errors will be the result.

This carefully averaged sample of 25 grains may be smelted either in muffle or open fire; but, if more is taken, the larger crucible will require an open fire.

It will be advisable to assay in duplicate, when exactitude is required; and to withdraw at the separate periods of fifteen and twenty minutes, so that the larger of the two buttons may be accredited for value.

If copper is present in the ore, a more moderate heat, and less time, may be advantageously given, so that as little copper as possible may be reduced therewith.

Copper may be also dissolved out from the weighed sample, by a little dilute sulphuric acid, then watered, poured off, and dried over lamp, sand bath, or other convenience, before fusion. (See the lamp, Cut 32.)

2. ASSAYING OF LEAD AND ANTIMONIAL LEAD ORES, BY THE "WEE PET" MACHINE.

A. Carefully prepare the sample for average, as directed in Chapter I, Section III.

B. Balance the lever with weight A, so that the *pointer* of the *main lever* may lie opposite the *line* on the end of the *transverse lever.*

C. Carefully remove weight A from the scale scoop, and place the weight marked B therein, in the manner described under headings A, B, C, D, E, F, G, and H, pages 250, 251, 253.

D. Shovel the ore into the other end of the scale scoop, until the *weight B and this ore* again bring the *pointer* of the *main lever* to balance with the line on the cross lever, and it will conform to the quantity marked 1000 (against weight marked X 4), on the No. 4 column, under the calculating lever.

E. Return weight B to the weight-box, unhook the scoop, and drop the weighed sample into the concavity of a prepared charcoal assaying-cup, and cover it with a mixture of one balancing (10 grains) of carbonate of soda.

F. If pure lead is required, the lamps may be now lighted, and the sample almost covered by a piece of solid charcoal (properly clasped in, and suspended by, the spring-fingers, as shown at page 138, by Cut 15), or partially covered by a furnace of fire suspended thereover (as shown by Cut 21, page 249), and smelted for some ten or fifteen minutes, as described under headings T, U, V, W, pages 256, 257, on the Silver Assay by "Wee Pet" machine.

G. Remove the resultant button of lead from the support, clean it from slag, etc., balance it with one of the numbered weights, marked X 2, X 3, X 4 (as described at page 261, under heading Z 1), and the button will lie opposite its fraction of 1000, and will thus expose its thousandths at sight.

Decimate the last right-hand figure (or divide by 10), and its percentage will also be known.

Thus, say it balanced with weight X 4 (in the scale scoop),

opposite 800, in No. 4 column; this would be 80.0 per cent.

If, at another time, it balanced with weight X 2 (in the scale scoop), opposite 72, in No. 2 column, this would, when decimated, equal 7.2 per cent., which is sufficiently low for practical purposes. If, however, you would value still lower, use the weights marked 4, 3, 2, and 1, and decimate two right-hand figures.

H. If antimony is also required, take the same weight of ore as before, but flux with one balancing (10 grains) of carbonate of soda, and with another balancing of the cyanide of potassium, when the total will represent the alloy of lead and antimony, and the *difference* of the percentage of these buttons, produced from the separate fluxings, will (as in the crucible assay) give the percentage of antimony.

3. Assaying of Lead and Antimonial Lead by Common Blow-pipe.

A. *For obtaining pure lead*, take one grain of pulverized ore, and two grains of carbonate of soda, which intimately mix together, and smelt in a paper cartridge for ten minutes, *in* a good yellow reducing flame, as fully described under heading 18, at page 239 for the Assaying of Silver by Common Blow-pipe.

Clean the button from slag, and hammer it very thin; if the edges remain unbroken, and the disk can be repeatedly bent across the middle without breaking, the metal is sufficiently pure; if not, re-place it on the charcoal, and warm it with an intermittent flame, but just to molten state, for a few seconds, and repeat the test of flattening, etc.

B. If antimony is also present, flux with an intimate mixture of one grain of carbonate of soda, and one grain of cyanide of potassium, which cartridge and smelt, as before, for ten minutes.

This cleaned button will contain *both the lead and antimony*, and the weight of lead from A being deducted from that of the alloy, the quantity of *each can be known*.

With a good balance, a carefully averaged sample may be thus most readily and correctly assayed; and the good blow-

pipist requires no better means than this for the practical purposes of mining and reducing lead ores.

4. Assaying of Lead by Water Concentration.

A. Galena (or sulphuret of lead) is found in very many mines, in a state of complete isolation from antimony and other heavy minerals; and, where such prevails, a more accurate, economical, and expeditious assay can be made by water concentrations of its mineral elements, for its equivalent quantity of metallic lead, than by any other method whatever. This may be accomplished in the following manner.

Take 100 grains from an average sample prepared after the method of Chapter I of this Section, and carefully concentrate it thrice, by the manner fully explained in Chapter III, at page 130; after the several concentrations are collected into a plate, saucer, bowl, or other suitable vessel, it may be thoroughly and safely dried, at the suitable temperature, by being placed, as a lid, over a sauce-pan or coffee-pot of boiling water (as shown by Cut 28).

Cut 28.

This dried residue may be next transferred to a *previously balanced* paper, and weighed for its percentage of galena, which, being multiplied by 86.55 and divided by 100 (or by the decimal numbers .8655), its actual percentage of metallic lead will be ascertained; and, if this dried weight is multiplied by 4 and divided by 5, it will be about the lesser quantity that can be obtained by crucible assay, or from the more extensive smelting operations.

If a little iron or copper should be present, metallic iron can be extracted by the magnet, or they may be dissolved away from the concentrated ore, before it is dried, in a drop or two of diluted sulphuric acid.

This method gives proper credit to, and calculates from, the precipitate produced by natural reactions, rather than resort to the more tedious and difficult artificial manipulations, that require much more time, knowledge, attention, and expensive tools.

In lead mines that yield other ores than galena, it will be frequently found sufficiently near for the daily *working purposes* of the miner, *not commercial*, to first ascertain *how much metallic lead can be obtained from* 100 *grains of a thoroughly concentrated sample of such ore, by crucible assay;* and, instead of using the former multiplier for galena, to *substitute the one thus created for his individual purpose*, to ascertain the produce of such particular, yet sufficiently equable, ores.

There are no *very easy* and *reliable* methods for assaying of lead ores by acids, etc. (suitable for your purposes), unless you have some chemical knowledge, and the facilities afforded by a laboratory; and, seeing that the above more appropriate methods are always at hand, it will be unnecessary to describe any of the purely chemical ones.

The percentage-calculating lever, illustrated by Cut 31, Chapter X, under the heading for "*Assaying of Copper by the Common Blow-pipe*," will be very useful for general practical purposes, as it suits *any weight of ore* taken for assay, when the resultant button is balanced on the longer end.

CHAPTER IX.

ASSAYING OF ANTIMONY.

1. By Crucible.—There are many uncertain fluxes used for assaying antimony, and one that is more efficient and trustworthy than all others; its only disadvantage being that it is somewhat more costly and scarce. I have endeavored to reduce the number of the fluxes as much as possible, and to simplify the operations of assaying, when certainty and efficiency are not endangered; and as this flux greatly favors these intentions, by often reacting in a manner not only peculiar to itself, but superior to all others; the trifling difference of its cost should be no barrier to its use, where it is preeminently serviceable in so many instances. For your occasional purposes, even this disadvantage is much modified from the fact, that the larger assortment of many others, are thus rendered unnecessary.

To 100 grains of the intimately mixed pulverized sample, add 300 grains of cyanide of potassium, when the ore is nearly pure, or in proportion to what there is in the sample (which may be ascertained by water concentration and calculating scales, on the antimony line, at page 224, as it happens to agree with nitre); and it may be then thrown, in mixed condition, into a crucible, and placed in a moderately hot fire; the crucible should be watched, and, in ten minutes after it has arrived at a red heat, it may be withdrawn from the fire, and quickly poured into an iron mould, or allowed to get cold in its place, when it can be extracted by fracturing the crucible, and then weighed for its percentage.

2. When Galena is also Present—It must be fluxed in proportion, as at page 290, for the ratio of both metals; smelted, and calculated for each as there directed.

3. THE ASSAY OF ANTIMONY BY BLOW-PIPE—Is not reliable when pure antimonial ore is treated; but, when mixed somewhat with lead as an alloy, it may be then reduced as at page 292, under "Lead and Antimony."

4. THE ASSAY OF ANTIMONY BY MACHINE—Is not practical, any more than by common blow-pipe, only when mixed with considerable lead; for which see, at page 292, for such alloy.

5. ASSAY OF SULPHURET OF ANTIMONY BY WATER.—When free from other minerals, it may be concentrated, as fully described at page 130, and under heading 4, page 293, for the "Lead Assay;" dried, also, as shown by Cut 28; and the percentage of metal may be known by multiplying it by .73. In working a mine, any peculiar multiplier may be also obtained as *under lead*, for approximate working purposes.

So, also, for such approximate practical working purposes, on the same mine, from similar ores, advantage may be taken from its extraordinary volatilization under the action of heat, and comparisons from actual assays may be made, and tabled for reference when required; thus, if a sample of 100 grains of sulphuret of antimony, of known crucible assay percentage of metal, after having been placed in a previously balanced or weighed clay scorifier, crucible, or roasting-cup, should diminish in weight, after say twenty minutes' roasting in a stove or other fire, at a red heat, a certain percentage; it will, when tabled in another column, opposite the real assay, serve as an approximate guide for future occasions.

THE HUMID ASSAY OF ANTIMONY—Can be correctly performed but by the experienced chemist, with ample acilities.

CHAPTER X.

ASSAYING OF COPPER.

The methods both for sampling and assaying copper have been, to a great extent, dictated by the smelters, who have been dealing with the miners very much in their own way; and therefore the "produce," or percentage, is governed more by *conventional minimum modes* than by the *real quantity* of copper in the ores.

1. The Assaying of Copper in Crucible, by the Cornish Method—Is recognized by all the smelters, and may be performed with the following fluxes, in the manner described.

Common salt, *in its damp state.*
Common salt, *perfectly dried by heat.*
Fluor spar.
Lime.
Borax. ("*Borax glass*" *is much better.*)
Nitre. (*Nitrate of potassa, or saltpetre.*)
Charcoal.
Tartar. (*Cream of tartar, or argol.*)
Sulphur, and sulphuret of iron, free from copper.
White flux.

All of these must be pulverized.

The latter you may prepare, when required, by mixing six tablespoonfuls of tartar with four of nitre and one of dry common salt, in a mortar; and then stirring them for a few minutes, with a red-hot iron bar.

Those who would become acquainted with all the several details of the varied mechanical manipulations and chemical reactions produced in the Cornish method for the crucible assay of copper, may consult the elaborate description con-

tained in the large work on Metallurgy, written by John Percy, M.D., F.R.S., Lecturer on Metallurgy at the Government School of Mines, London; whilst the following will suit the requirement of the miner.

Prepare and pulverize the dried sample for average, in the manner described in Chapter I, Section III, noting the upper side of the sieve for flattened disks of metallic copper, which, if found, must be calculated separately, as previously described for gold, silver, etc., from the whole weight of the sample; or thus: If say 1900 grains of sample yielded 23 grains of such copper, what ratio would 100 grains (or any other quantity taken for assay) have yielded? Which may be known by multiplying the weight of 23 grains, thus obtained, by the 100 grains (or any other weight taken for sample), and dividing this result of 2300 grains by 1900 grains, the total quantity from which the disks were obtained; and as in this case it equals 1.21 per cent., and robs the assay that much, it must be added to the percentage obtained from what did pass through the sieve.

To do away with all these tedious collateral manipulations, calculations, etc., unless the copper is in excess, I prefer to completely dissolve the copper thus derived, in a minimum quantity of sulphuric acid; and then, after diluting the solution a thousand fold with water, to scatter the solution drop by drop throughout the whole pile of ore, before it is dried (so that one drying may suffice); then to well mix, both before and after drying, ere the sample is weighed. The more equable result obtained is of greater consequence than the very slight error occasioned by the weight of the few drops of acid thus added to the whole pile, which can, however, be allowed for, if necessary, by taking the proper ratio of ore in addition, when weighing for the assay.*

An excess of the quantity required for assay must be taken, and dried at 212°, the boiling temperature of water, so as to have sufficient surplus for repetition of the assay, in case of accident, and for preliminary examination by water (as previously described in Chapters III, IV, and V, Section

* In gold and silver assays, the former may be thus dissolved by two drops of hydro-chloric, and one of nitric acid; and the latter by nitric acid, then diluted and intimately mixed with the whole sample, in a similar manner.

III, on "Discrimination of Minerals for Practical Purposes," etc.), to ascertain, in this case, whether it belongs to the class of copper ores denominated by Cornish assayers the "Raw Sample," which contains little or no sulphur; or to those called by them the "Warm Sample," which contain much sulphur, and require preliminary roasting.

The quantity of ore taken by Cornish assayers for the assaying of copper is varied, so as to obtain a button of suitable size, etc., whilst several of the fluxes remain, in consequence of this, about the same.

A weight of 400 grains has been chosen to represent a suitable quantity for assaying of the poorest ores, which is divided into hundredths, and again into *eighths of one unit*, of such percentages, to represent the market "produce."

For ores under 10 per cent. of copper, 400 grains, or their 100 weight, is taken.
Those above 10 and under 30 per cent. of copper, 200 grains, or their 50 weight, is taken.
Ores that exceed 30 per cent. of copper, 100 grains, or their 25 weight, is taken.

And it may be as well for you to do the same.

It is then performed by six or seven separate operations, as follows.

A. Roasting to Expel the Sulphur.—Weigh the dried sample, and, if it requires roasting, place it in a crucible about four inches high, so that the ore may have sufficient room for being stirred, without causing it to escape over the edge. Warm it to red heat, stirring continuously with a small rod of iron; the mouth of the crucible should be slightly above the fuel, and inclined away from the draught-hole that leads to the chimney, so that the air may more readily enter and oxidize the ore.

The roasting may be completed in from fifteen to thirty minutes; and if it has an earthy, pulverized appearance, it has been effectually performed; but, if such has not been accomplished, another sample should be substituted, for better realization of such desideratum.

B. FUSION FOR REGULUS.*—The unroasted, or this *roasted* sample, may be intimately mixed, and fused in the *same* crucible, with equal weights of borax glass, fluor spar, and slacked lime, then covered by a layer of common salt.

After the crucible's contents have become *thoroughly molten at a high temperature*, when treating an unroasted sample of very low grade copper pyrites, a little nitre should be added; so, also, when the raw sample does not contain any sulphur, about 20 grains of sulphur may be added, to have sufficient present to produce a good regulus; then a little lime, fluor spar, and borax, are again added, and, when thoroughly fused to fluidity, the contents must be poured into the button mould; and, as soon as it has solidified, the mould is emptied into a shallow water-trough, to remain until the adhering slag can be the more readily separated from the regulus. The regulus should contain from forty to seventy per cent. of copper, and be of a bluish bronze color, with considerable metallic lustre; but neither too dull nor too bright.

This button of regulus must be very finely pulverized in a mortar, with a little charcoal or coke, care being taken that none is lost, either over, or by sticking to, the mortar; then transferred to another similar sized crucible, for re-oxidation by secondary roasting.

C. ROASTING THE REGULUS—Is effected by placing the crucible on the fire, warming it gradually during continual stirring with a steel or iron rod, for about twenty-five minutes, until it shows an earthy appearance, and all sulphurous fumes have ceased.

D. SMELTING OF THE SULPHIDE REGULUS FOR IMPURE COPPER.—Mix (in the same crucible) with this "roasted regulus" 25 grains of nitre (nitrate of potash, or saltpetre), 25 grains

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* In fluxing for regulus, the effects sought are a fusible slag (produced by borax and fluor spar), which shall also contain the copper, etc., when oxidized and fused to sulphide forms; hence, the addition of sulphur, or sulphurets of iron, to certain ores, that do not contain sulphur in their natural constitutional forms.

The lime facilitates the separation of the lighter stratum of the slag from the regulus.

of borax, 15 grains of coal powder, 100 grains of *dry* salt, and 200 grains of tartar. Cover this mixture with a table-spoonful of common salt.

Place the crucible in the fire, cover it with a piece of coke or charcoal, and heat it as quickly as possible, for about fifteen minutes, or until perfectly fluid; then, after adding a little white flux, to oxidize the foreign metals, and allowing it to remain a few minutes longer, it must be removed from the fire, a quick circular motion given to its contents, to wash any globules of copper from its sides, lightly tapped on the furnace, so as to precipitate them to the larger button at the bottom, and then poured rather hastily into the previously greased iron button-mould; and the crucible returned to the fire for the next stage of the assay, that of the further oxidation of the associated metals, called "Washing." *

E. "WASHING," OR FUSION WITH FLUXES.—The impure button from the smelted regulus is now placed in the white-hot crucible, for the further riddance, by oxidation and chlorination, of the associated metals, by the assistance of 100 grains of white flux and 200 grains of dry salt.

It should now remain *perfectly fluid* for five or six minutes, and be again quickly poured into the iron mould, for further examination by hammer, etc.

It should, when brushed clean, be comparatively pure, or this "washing" must be repeated.

F. REFINING THE "WASHED" BUTTON.—It is first cleaned, then hammered thin; if it is *hard*, tin is still associated therewith; if it cracks around the edges, antimony; and if in the least yellow, zinc. If of undoubted color, softness, and tenacity, it may be now weighed for percentage; but, otherwise, a clean crucible must be properly fixed in the fire, until it becomes *white*-hot, and the button placed therein and carefully watched. It should quickly melt, to a *hazy* semi-globular shape, but *immediately* the edge loses this appear-

* In this operation, the salt rendered the mass fusible, and formed volatile chlorides; the borax served as a flux; the nitre passed off the sulphur; the tartar and coal powder, by forming carbonic oxide, reduced all the oxidized copper to metal; when the addition of white flux passed off the other associated metals by subsequent oxidation.

ance, and becomes most *distinct in outline*, and the centre shows a *dark variegated* appearance, an equal (previously prepared) mixture of 50 grains of white flux and dry salt must be promptly added, and in about five minutes the molten contents may be poured into the iron mould, when the button should stand all the tests for pure copper, and be weighed for percentage.

G. All the waste Slags are Saved from these Several Fusions, and Re-smelted—In a suitable sized crucible, for fifteen minutes, with 100 grains of tartar and 20 grains of pulverized coal or charcoal; it is then poured into the mould, and the copper again refined when necessary, and the weight of this "prill" added to that from the assay proper.

The kinds and quantities of the fluxes given are for general application, rather than for varying percentages; for which some would have to be increased and others diminished as occasion required, so as to economize fluxes, etc., to suit the ever-varying ores.

It will be almost impossible for an amateur to become very proficient in this matter, beyond the practice of varying the weight of the sample taken for assay, according to the percentage of the supposed metal in the ore, which a practiced eye can closely approximate. The Cornish assayers, although working entirely upon the *more simple copper ores*, each day of their lives, do but approximate to rigidly accurate quantities; as too much time would be required in calculations and weighings for more exact chemical proportions.

In fact, this comprehensive manner of assay alone permits such irregularity, *when the fluxes are in excess*, for the following reasons.

The roasting partially desulphurizes; the several fluxes used for producing greater fusibility are *otherwise harmless*, even when in excess; the sulphide slag is directly produced by the uncontrolled strength of the sulphur's affinity for copper, etc.; the oxidating fluxes are prevented from wasting, by the excessive quantity of the reducing fluxes that are used: the manipulation is therefore more likely to cause error than the fluxes.

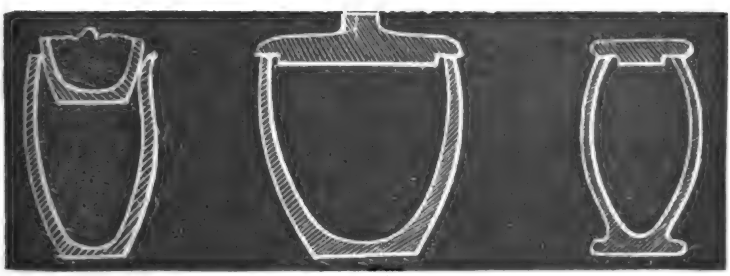
The upper part of the furnace, under the cover, H (as illus-

trated at page 229), is also adapted for this copper assay, and the muffles can be used for roasting as well as for assaying copper by the German mode.

Beyond the deplorable fact that this Cornish method of assaying copper is demanded by the smelters, and that, *apart from the fluxes*, it somewhat resembles smelting on the large scale, there can be no other reason for favoring or retaining such a tedious, difficult, expensive, unsatisfactory, and low percentage method for assaying.

2. Assaying Copper by the German Method.—This, the favorite means used in Central Europe for the fire estimation of copper, having less smeltings, etc., is more speedily accomplished; and as it can be entirely performed in the muffle, without the slightest inconvenience, instead of the open fire (which requires constant attendance), not only a much greater number of assays can be made in the same time, but the operations are seen to progress in a perfectly

Cut 29.



French. Cornish. German.

regular manner, immediately under the eye of the assayer; and, whilst it is more truthful in comparative results, the exaction of the percentage of copper approaches much closer to the real quantity of metal that the ore contains.

The general-purpose furnace illustrated at page 229 will be found very convenient for this purpose, and either stone-coal, coke, or charcoal, may be used; which must be regularly supplied at the top with the greater portion of the fuel, to keep it at about four inches below the cover, H; whilst a little should be put through the hole, F, under the muffles, to regulate the heat as required. Cut 29 illustrates the crucibles that are adapted for this assay.

The vessel best adapted for this assay is the expressly shaped, barrel-sided, expanded bottomed German crucible, which stands more safely in the muffle, whilst the bottom of an old crucible, when broken at the *contraction* just above the bottom, *when inverted*, serves most effectually for covering the next assay. The short, capacious Cornish crucible, that is supplied with an especial cover for close assays, will also answer very well for this purpose; or the French general-purpose crucible, that is also shown on the right of the scorifier, on the front of the furnace, at page 229, where the wooden-handled iron button-mould, the tongs, and the spring-clip lie.

This process is divided into three separate fire treatments, and those are "Roasting," "Smelting for Impure Copper," and "Refining."

The following fluxes and substances are required for this mode of assay.

Graphite; or charcoal, pulverized.
Common glass, pulverized.
Borax glass, pulverized.
Common salt, dried and pulverized.
Arsenic (metallic).
Lead (granulated).
Black flux.

The last may be prepared by *intimately mixing one measure* of pulverized nitre to *two measures* of pulverized crude tartar, and stirring them with a red-hot iron wire, in a clean and capacious warm crucible.

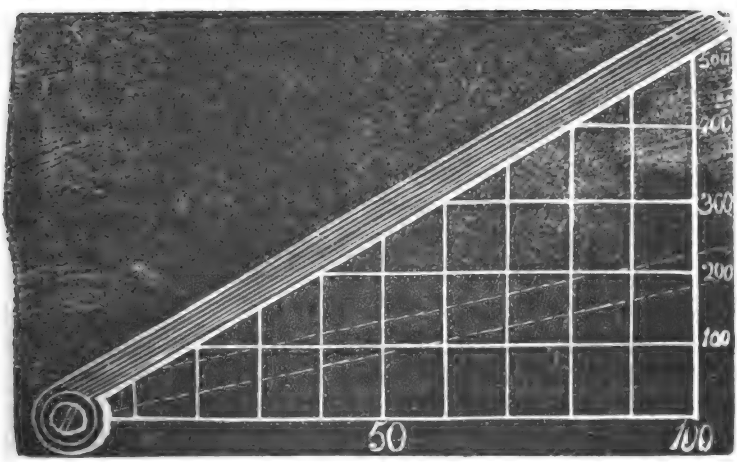
A. Roasting.—As a smaller quantity (60 grains) is taken for the German than for the Cornish assay, just described, you should prepare your sample with even greater care, so that it shall be homogeneous, by the directions given, in detail, in Chapter I of this Section.

The same precautions being taken about metallic copper as have been fully described at page 298, for the "Cornish Assay of Copper," you may weigh out 60 grains of dried ore; mix it with 15 grains of graphite, and spread it over a scorifier or roasting-cup (which has been previously rubbed

with red chalk, or smeared with red ochre, to prevent the ore sticking thereto); then place this one, or more of such, in the muffle or muffles, and carefully roast for fifteen minutes, stirring it nearly the whole time with an iron wire; if, on removal, the ore still smells of sulphur, it must be re-pulverized, mixed with 15 additional grains of graphite, and be again roasted.

When this has been well performed, the sample appears earthy, and is still fine; but, otherwise, it has a coarse, clodded, slaggy, or metallic appearance; and either the stirring has been neglected, or it has exceeded the low red heat that is alone adapted for this operation, with some fusible associates, as antimony, lead, etc.; and should be discarded for repetition on *another* sample.

Cut 30.



Those who would study and practise exact economical fluxing will find the Ratio Calculator of Cut 30 very efficient. The base line should be divided into 100 (or any number of units taken for the assay), and the perpendicular into 500 units, for the greatest quantity ever required of any of the fluxes; so that when the swivelled hypotheuuse is moved down (as shown by the dotted lines) to the desired quantity of flux for the whole amount of the assay, a vertical line from the actual concentrated quantity to the hypothenuse will, when measured on the end scale by a compass or rule

be the number of grains required. Instead of measurement, *perpendicular and horizontal lines* may be drawn from every unit, so that the eye may pass up from the quantity of ore as shown on the base line, to the hypothenuse, and thence along, by way of the horizontal line, to the exactly suitable quantity on the vertical scale at the end.

B. SMELTING FOR IMPURE COPPER.—The sample, having been thus ridded of the more volatile sulphur by roasting, still contains the unaltered gangue with the copper, iron, lead, tin, zinc, etc., in more or less oxidized states. The next ensuing results to be obtained are, the fusion of this gangue into a molten condition, which unites with the oxides to form slag, by finely pulverized borax glass, or common window glass; whilst the copper, being reduced by "black flux," is precipitated in a metallic shower to the bottom of the crucible, to form the one button of "impure copper."

Take either of the crucibles alluded to, as shown by Cut 29, of as large a size as the muffle will freely receive, and treat the roasted sample in the following manner.

Carefully transfer the whole of the 60 grains of roasted ore into a mortar, and, after adding thereto 60 grains of black flux, they must be finely pulverized, intimately mixed, and then placed in the bottom of the crucible. Upon this mixture place a layer of 120 grains of black flux; then another layer of 25 grains of common glass; and still another of 15 grains of borax glass; these are again covered by a teaspoonful of common salt; then, a half-inch cube of charcoal being placed on top, the cover is put on, and the crucible is placed into the *moderately hot muffle*, and *very gently heated* for some ten or fifteen minutes, as the first action would otherwise boil some of the contents over the crucible, and cause a loss. This stage being safely got over, the muffle may be heated to whiteness for some thirty minutes longer, when it must be removed from the fire, and after being lightly tapped, to settle the metal to the bottom, allowed to get cold, when the button may be obtained by breaking the crucible.

The surrounding slag should not be red—which would be caused by copper—but brittle and dark green; nor should

the metallic button be encrusted with unreduced dark sulphides.*

C. REFINING THIS SMELTED BUTTON.—This process is intended to produce the same effects as the refinage in the Cornish mode; but it is done in a very different manner, with borax alone, which forms a slag with the other base metals that oxidize sooner than copper; so that if, at the *exact moment* when the last one of these has just departed, the button be withdrawn from the muffle, it will retain nearly all the copper that the sample contained.

A small piece of the side of an old crucible, that has suitable concavity, and sufficient stability to retain its position, is placed in the muffle, and brought to a white heat by being partially covered with a piece or two of charcoal, whilst the furnace fire is simultaneously urged to the necessary degree of heat to readily melt copper.

The button that is to be purified is wrapped in a small piece of strong paper, with its weight of borax glass, and by the aid of tongs (seen on the right of the furnace, Cut 20, page 229)—or, *better and safer*, by the *self-closing spring forceps*, that lies on the left-hand side of said furnace—it must be placed in the concavity of this white-hot crucible side, just where it can be most distinctly seen. The door of the muffle (I use bricks, endwise, instead of doors) must be left open, so that a current of hot air may pass over the button, to oxidize the objectionable metals.

Shortly after fluidity is attained, the characteristic wavings of various colors will be seen; then it will have, for a few seconds, a greenish, pearl-like appearance, and, if the muffle is insufficiently hot, it becomes solid (as pure copper melts but at a certain higher degree); or, when the heat is above the melting point, it assumes a mirror-like, fixed surface, and should, in either case, be immediately withdrawn from the muffle, and slowly cooled by gradual immersion in water.

The copper button, being now extracted from the slag,

* When the ore is rich in copper, and entirely free from lead, in addition to borax and common glasses, about 10 grains of metallic arsenic may be advantageously used for the production of still more fusible slag, and the precipitation of all the copper.

should have *copper-like* brightness, with a smooth, rounded surface, and, when hammered or rolled very thin, be so soft, malleable, and tough, that the periphery of the disk shall not expose in the least degree, when examined by a lens, any cracks, or appearance of approaching fractures. The *weight in grains*, multiplied by 10 and divided by 6, will give the percentage of copper in the ore.*

3. Assaying Copper by the Common "Mouth Blow-pipe."—This is the most easily obtained itinerant means for the estimation of the percentage of copper from its ores, for those who have obtained, from long practice, the necessary manipulative skill to produce correct results.

It, however, in this country, costs about $100 to provide the necessary tools for its accomplishment, by the mode described by Professor Plattner and Dr. Sheridan Muspratt, in their large work on "The Qualitative and Quantitative Examination of Minerals, Ores, Furnace Products, and Metals, by Blow-pipe;" as well as the instructions given by the other subsequent authors, who have but repeated these far-fetched elaborations; so that the *poor* amateur is entirely excluded from the little blow-pipe's wonderfully great advantages, from mere want of funds. To such (who should be studied and respected none the less because of struggling, honest poverty), I submit the following, for practice, to ena-

* The worst features in this method are, that, in ordinary muffles, very small crucibles have to be used, with considerable quantities of the fluxes, so that the black flux of the latter, from rapid action, frequently effervesces over the edge of the former, and consequent errors are thereby occasioned.

For these reasons, I have found it much better to use, with the same quantity of the fusible, *slag-forming* fluxes (of common and borax glasses), but half the quantity of the "black *reducing* flux," and to vary the weight of the sample taken, according to the percentage of copper in the ore.

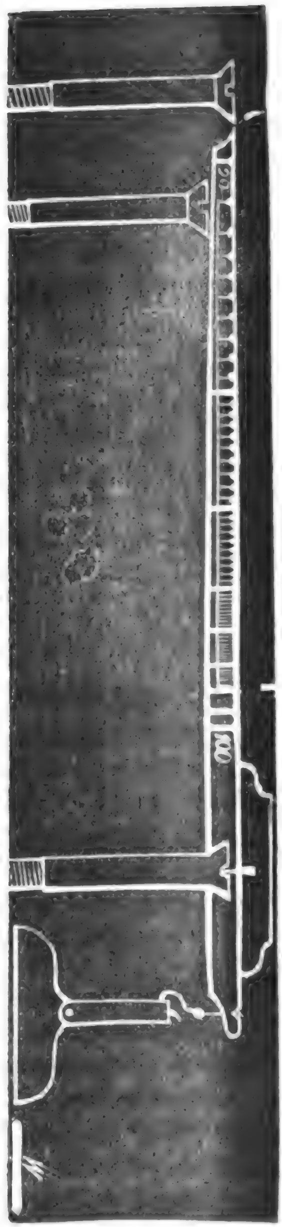
For all ores at about, or under, 25 per cent., take the full 60 grains.
" " " " 50 " " only 40 "
" " " " 75 " " only 20 "

The percentage of metal may be then as readily known by multiplying the respective weights of the buttons derived from each by 10 and dividing by 6, by 4, and by 2.

By this percentage of metal change, 100 grains may be as effectually treated for the maximum quantity, etc., as the 60 grains are by the above general manner.

ble them to arrive at results that will be frequently found sufficiently near for approximate practical purposes. (Those who can afford the necessary outlay may refer to the first named work, for the commensurately advantageous instructions therein contained, regarding modes for manipulation, tools, etc., etc.)

Cut 31.



The cheap and efficient common tin blow-pipe, with brass nozzle, suggested by Dr. Black, is all that you will be compelled to buy.

A. Make a Balance for Weighing the Sample and Calculating its Percentage of Metal—By cutting a strip from the side of a perfectly dry cedar cigar-box, about three-eighths of an inch wide, exactly parallel from end to end, and the thickness of the wood. Divide its upper side with a compass just exactly like that shown by Cut 31, by keeping the one leg always on the second mark from the right hand (which is where the knife-edged fulcrum is shown), and measuring and marking, by transverse notches, the respective distances therefrom of each unit of per cent., from 80 down to 20; which are sufficiently high for the constitutional percentages of both copper and lead, and as low as can be profitably disposed of, without farther concentration; then, after still farther marking every *ten* (at 90, 80, 70, 60, 50, 40, 30, and 20), down the nearer side of the beam, it is ready for having a broken *pen-knife blade* inserted for a fulcrum, in the manner shown, and which is secured in posi-

tion by having a short piece of similar wood, glued, pasted, or pinned down thereon. (Twice this length is better, as it allows the whole distance to be divided into units.)

A pan may be now cut out with strong scissors from one piece of thin brass, so as to form both pan and loop, with holes through the sides sufficiently large to receive the small wire hook that is attached to the thread for that purpose, the thread being passed up through a small hole made by a pin for its reception, and which is prevented from returning by a small rounded knot, or it may be made just as it is shown.

Two iron or brass screws are next to be screwed into a board, at suitable distances apart, with their gaffs in line, properly filed to **V** shape, so as to receive the knife-edged fulcrum of the lever; another screw is inserted opposite the pointed long end of the lever, that must now be balanced by cutting, filing, or scraping away from the pan, that is *intentionally made* too heavy, *for this purpose;* whilst a third lies underneath, to serve as a suitable stop and rest.

A weight may be now made (which should be about one grain, the quantity suitable for the mouth blow-pipe), that may be made by cutting off a piece from an ordinary sized pin, five-eighths of an inch long, marked W in the sketch. It need not be exactly one grain.

To weigh out the assay, this weight must be placed in the groove over the 100 mark on the long end of the lever (after the lever is correctly balanced to the head of screw, by a short piece of a lucifer match placed on either side of the fulcrum, just where it is required for balancing the lever), the pulverized and very correctly averaged ore being then placed into the scale-pan until the other end returns to stand exactly oppo e the top of the screw.

Thus, it will be equal to this weight, and when smelted into metal, alth ugh the actual weight of the sample is unknown, *its percentage* of metal will be ascertained, either for this or any other quantity taken for assay, when rolled in or out to balance with this, the weight of the assay, in the pan.

B. The carefully averaged sample may be first weighed in this manner, and transferred into either a common sewing-thimble, or empty pistol-cartridge.

C. If the copper ore is a sulphuret, it must be roasted, and, in the absence of other tools, it may be very efficiently performed as follows.

Take a piece of thin iron, or a piece of tinned iron plate from a sardine or oyster can, from which burn off *all the tin*, by heating it to redness in a common or sage-bush fire; cut off a square of one inch in diameter, and, by cutting a suitably shaped recess in a log of wood, hammer it with the rounded *end* of another small stick of wood into the shape of the large end of a pigeon's egg, when it will serve for a roasting-cup.

Now take a piece of charcoal—a small branch of one inch and a half diameter and about four inches long will answer best—and scoop out with your knife, from the middle of one end, a concavity to receive the cup, so loosely that the heated air shall freely pass up around it during the roasting, whilst it shall be also kept clear from the bottom by the four sharp angles of the square being bent outwards over the top of the charcoal. This being done, drill a small tunnel in the side of the piece of charcoal (with your pen-knife or a sharp piece of hard wood), about a half-inch down from the top, to communicate with the bottom of this roasting pit, and your roasting furnace is ready for kindling. Next place the weight in the notch over the mark 50, and balance the lever by placing sufficient powdered charcoal in the scale-pan (it will be twice the weight of the assay); transfer it to the thimble or cartridge, and mix it thoroughly by shaking it between the finger and thumb, and place it in the roasting cup, and thence into the furnace. Light a miner's candle, if you have no blow-pipe lamp; or make a lamp, by placing a rifle cartridge into a common broad-based angular inkstand, with the flange upwards in the position of the cork, and drill or pierce a hole therein of three-eighths of an inch diameter, to receive a cotton wick. This, being supplied with olive oil, is now ready for being lighted up for use.

With the piece of charcoal in the left hand, the lamp on a table, and the pipe in the right hand, you may blow the whole of the flame from the candle or lamp into the tunnel, which will, by lighting the fire below and around the roasting cup, quickly bring it and its contents to a low and suitable

red heat, which must be continued for some ten or fifteen minutes, excepting short stops of a few seconds for stirring the ore with a very small strip of pointed wood, a needle, or pin. If it still smells of sulphur, it must be again roasted with a little more charcoal, until sulphur ceases to be evolved.

D. Smelting for Crude Copper.—Transfer *the whole* of this oxidized ore from the iron dish into the thimble or cartridge, and after adding thereto the same weight of carbonate of soda as was taken of the mineral for assay, it must be intimately mixed, and carefully pulverized, without any loss.

E. Cut off a piece, about one and a half inch square, from strong letter-paper, and plaster the one side with a thin coat of common white soap, to within the eighth of an inch of its edges; it must be now made *sufficiently wet*, if it *is not already*, for the mixture of the ore and carbonate of soda to stick thereto, as it is now lodged in an equal manner over the whole surface of the wetted soap. By placing some very small point of something, with the left hand, in the centre of the paper, you must now fold each corner towards and down over the centre, and then gather the whole into a ball, without extracting any of the mixture of ore and fluxes.

F. Take the same piece of charcoal as was used for roasting (or a similar piece), and cut or saw off the ragged and burnt end; then sink a shaft in the end with your penknife, about three-quarters of an inch deep, and sufficiently large that the assay ball may *fall* to the bottom rather freely. Drill a tunnel, of about one-quarter of an inch bore, to this shaft, just immediately over where the fluxed sample lies, and it is ready for smelting, etc.

G. You must now be able to blow in continuously for some ten or fifteen minutes, through the tunnel, the whole mass of flame, at first but gently, until the assay has been well united together in state of slag, so that no loss may be occasioned, and then in such a manner as to produce the greatest possible heat. The greatest heat is not produced by a strong, but rather a steady and well directed mild blast; so

do not blow too heavily. The shaft may have a few pieces of charcoal thrown in, of about the size of split peas, which will assist the novice, by sustaining the heat for a moment, when he may be unable to keep up continuous blast; or the shaft may be *nearly* covered by a larger piece of coal, so as to increase the reducing effects of the fluxes, etc., on the ore.

It will be seen that the revolution of the assay, as described under "Silver" and "Lead," is prevented by this method, which matters but little for copper; and it has the greater advantage of being an actually enclosed smelting furnace, which, by both retaining and producing heat, as well as being in the very midst of the reducing element of carbon, the copper is much more readily reduced from the more molten mass, which can be rolled from side to side, or otherwise oscillated at the pleasure of the operator.

It is, moreover, much the easier in the ways of manipulation, fluxation, blowing, and smelting, for the amateur; whilst the close fire and superior reducing flux obtains copper from its refractory ores, when the open method (as fluxed by carbonate of soda and granulated lead, and oxidized by boracic acid) fails to do so. It will also smelt twice as much.

H. Refining the Coarse Smelted Copper.—The unbroken slag that retains the copper may now be removed from the furnace, and placed just as it is in a small concavity, that has been cut with the point of your knife on the outside of the charcoal, with about its weight of borax glass, and fused by the blue (oxidizing) flame for some three or four minutes, to oxidize the other more volatile metals away; during this, you should roll the button about in the slag, so as to unite the small globules, that may lie apart, into the larger central button.

It may be now cast suddenly off the coal into a saucer of clean water; then taken out, and the copper button examined for purity, as previously described for "Crucible Assay," and re-treated with borax, or weighed.

The slag may be re-smelted, too, if deemed advisable, with additional fluxes, or examined by water treatment, as explained at pages 152 and 153; and the copper *dried*, and added to the first button.

I. THE PERCENTAGE OF METAL—May now be ascertained by first balancing your calculating lever's pointer to agree with the top of the screw's head; then placing the assay's weight in the pan, and moving the button to balance on one of the units of percentage.

When the true balance is much above or below any unit, note how far it lies from the pointer, and, after removing it to the next unit, you will know tolerably well, by the distance the pointer then lies the other way, what intervening fraction of half, quarter, or eighth, to record.

This calculating lever will, of course, answer for all the other base metal assays; as will the shaft and tunnel mode for their smelting, when otherwise fluxed as directed under their different headings.

The balance lever may be also extended to twice the length of the 20 mark, so as to have a 10, which would be the one-tenth of the hundred; so that a weight could be then made to equal the tenth, and, being put in the pan, a balanced button would represent thousandths instead of hundredths; and, again, another might be made to represent ten thousandths of one grain, or any other pan weight.

An even beam may also be made to weigh instead of calculate, by having a similar piece of wood, etc., of double the length, and, by dividing the one or both ends into tenths, the weights may be also made for the decimal system.

Some years since, I required to make a gold assay, when beamless and weightless, in far remote and frozen-in winter quarters, where the mother of invention, Necessity, induced me to make an equal-ended lever, somewhat on these principles. The beam was a little over twenty inches long, one and a quarter inch wide, and seven-eighths of an inch thick, and was correctly divided and carefully notched at every inch of the right-hand end, so as to decimalize the lever for obtaining the necessary weights, either as regular weights or as **U** shaped riders.

These tenths were notched, both at right-angles across, and *down the nearer side* of the beam, and the intervening spaces were again severally divided and notched less distinctly across the top of the beam only.

The side and vertical notches were then numbered from the centre outwards, by three rows of hundreds, tens, and units, in the following manner.

100.	200.	300.	400.	500.	600.	700.	800.	900.	1000.
10.	20.	30.	40.	50.	60.	70.	80.	90.	100.
1.	2.	3.	4.	5.	6.	7.	8.	9.	10.

The 1000, the 100, and the 10, being over the scale-pan, the range from unity to the thousandths is thus completed by the use of riders. The upper side of the wood beam was straight, and the ends were sharpened to a point, which, with the central knife-gudgeon and supports, were all similar to those of Cut 31.

In the centre of each end or tenth mark from the gudgeon, holes were pierced by a small needle, and then made conical from the under side, whilst the upper part remained of the same size, so that the thread might oscillate.

After the lever was made thus ready for suspension, I screwed a short piece of plank against the window's side-frame, at a suitable height for cradling the lever in screws, similar to Cut 31, whilst one end of the lever passed sufficiently near the wall for a pointed wire to be driven therein to serve for stand-point for balancing the lever, and more subsequent weighing operations. The lever was now greatly reduced, by scraping with glass, or a sharp knife, from its under side, more particularly towards the ends; and, lastly, balanced, by scraping, to the mark, by changing ends occasionally, and raising or lowering the wall wire, if necessary, to its position of being exactly level with the knife-edged gudgeon, which the corrected lever proved for itself, as it attained more accurate balance.

Scale-pans were now made, by cutting out from the side of a square oil-can two disks of four inches in diameter, and then, after stamping three holes in each, they were threaded and brought to unite with one thread at the top, which was then passed up through the lever, and prevented, by a neatly rounded single knot, from descending beyond the proper position. A platform being then secured to the wall, just under these pans, they were then filed and scraped to balance, and the apparatus was ready for use. If it is not suffi-

ciently susceptible to small weights, scrape or scoop out from the *middle* of the under side of the beam, until it becomes so.

A "king-post" (and consequent double triangle stay) is quite an acquisition to such a beam, which it greatly stiffens, without interfering with the action of the riders, and, by upper weight, renders less under scraping necessary for the proper adjustments of the centres of floatation and gravity. It may be made in the following manner.

Cut a piece off from a cigar-box (one and a quarter inch wide), the width of the beam and three inches long, for a king-post; cut the bottom end to a sharp edge (to suit into the *central* transverse groove of the main lever), and taper the post from the full breadth at the bottom to about three-eighths of an inch at the top, and cut a neck about three-eighths of an inch down from the top to securely receive a small wire or piece of strong twine or whip-cord.

Now drive two strong nails into a board, about *an inch and a half further asunder* than the *extreme length* of your *wood beam*, and make a mark exactly midway between them, as an after guide for twisting the cord or wire.

Take a very small iron or copper wire (such wire as is used for securing the corks in the bottles which contain various effervescing drinks), or a piece of whip-cord, or strong twine, and, after doubling and tying it at the one end, twist it, by a short, round stick of the size of a pencil, or the "king-post" neck, held exactly over the mid-way line, until the wire hugs it closely, or becomes too tight by shortening, when each of the nails may be withdrawn from the wood, and again driven a quarter of an inch nearer to the centre mark, and then, after being again twisted, it will probably be ready for being placed in position on the lever, which may be done by cutting two gaffs or saw-cuts in each of the beams, and placing the loops of wire from the nails therein, in such a way that it shall take good hold, without splitting or fracturing the wood, when the wire is being twisted somewhat tightly, and the "king-post" is being twisted and sprung into position.

This post will not happen to be of the exact length to suit the length of the wire; but, being placed in position, and slightly wedged up by another piece below, the exact additional length will be ascertained, when another can be made

to suit. If the three points of rest (the gudgeon and the knots that suspend the pans) should be thus thrown upwards out of line, you may cut the end resting-points a little lower. By a little perseverance, you may make such scales very delicate in their action, when they will answer every practical purpose required in assaying.

To Make a Set of Weights—For *such a lever*, is a very easy matter, when you proceed as follows.

Borrow from the grocer's store his one-ounce, or half-ounce, or quarter-ounce weight, or a weighed quantity of hard, heavy material, that equals either of these, or any other weight that you may prefer for the nature of assay you would wish to make, as that for self-calculation, as described under heading 4, page 219, under Gold and Silver Assays; or, in fact, any quantity of anything—as a hornful of quartz, of no particular commercial weight—and by placing this in the one pan, you may take a piece of round brass or iron wire, of greater weight, and file it to balance, when placed in the other pan, so as to obtain just the weight you desire, and call it your 1000 weight, which must be now bent to somewhat of the shape of a letter ⊏, with sufficient space between its long legs that it may freely straddle the beam of the scales. Now place this 1000 weight in the 100 mark as a rider, and take a much smaller wire for a second weight, which make of the same shape as the first, and so diminish its weight, by filing and scraping, that it shall exactly balance the 1000 weight on the 100 mark, when placed in the opposite pan. Next, by placing this weight in the 100, over its mark of 100, and again filing, scraping, or cutting another much smaller piece of wire, or cord, or thread, to balance, and you will have a 10 weight.

Thus, you have decimalized the large quantity called 1000, and provided yourself with means to weigh any and all quantities, by these three weights, from the thousand down to its ten-thousandths' part, which I will endeavor to make more intelligible by explanation of the principle of its action, with examples.

The 1000 weight is always used in one pan to weigh the assay in the other, which, being fluxed and smelted (and

cupelled, if gold or silver), the clean button is then placed in the left-hand pan, and weighed by the use of movable riders, instead of fixed positioned pan-weights, as follows.

Now we will first suppose it to be a base metal assay, for per thousandths or percentage, and proceed as follows. The button is placed in the left-hand scale-pan, and the 1000 rider on the other end of the lever, on the *side*-mark, where you think it will balance (say 600); but it is not so heavy, and the rider is tried on the 500, where the button is still too light to balance therewith, and the rider is placed on the 400; the button is now found to be heavier, *as it always should be*, when this 1000 is allowed to remain exactly on the 400 mark, and the 100 rider-weight is now tried from out to inwards, in similar manner, until it also lies exactly over a line, when the button is heavier than the riders (as on say 70 in its own, the second line); now the third, or 10, must be placed until it does exactly balance, and this weight—*differing from the other weights, which must keep over the lines*—has the sole privilege of settling the balance, by traversing the whole 100 divisions, if necessary to balance; which, in this instance, shall be over the second mark outside of the 1 in in its own third line.

The per thousandths of such a button will therefore be 471.2 (and the percentage 47.12), and the value of the bullion or ore may be obtained by multiplying it by 37.7 for silver, or 602.73 for gold.

As another example, a gold assay made from this 1000 weight may balance its button when the weight 10 is on the first top-notch from the centre of the beam, on the one-hundredth of the half-beam's length, which would be the tenth of the *unit* of one-thousandth, or a decimal .1, which, being multiplied by 602.73, would be equal to $60.27, a quantity still too high for the gold assay of low-grade rock; so that, for such a purpose, a fourth weight, marked 1, would have to be used, and, when used in the position the 10 weight just occupied, it would represent the *one-hundredth* of the unit of *one thousand*, or the decimal .01, which, being multiplied by 602.73, will equal $6.02 per ton of 2000 pounds. (See headings 3 and 4 of Chapter VII, for general principles for calculation of gold and silver per ton, at pages 217 and 219.)

It will be seen, from the above remarks, that the third, or weight 10, should be used as the smallest weight for silver assays, whilst the fourth is necessary for gold; and whichever may be used, *being the smallest* of the 3 or the 4 weights, it will have the privilege of ranging the whole length of the beam, for the lower decimation of the weight.

In general weighings of buttons from the ordinary milling and smelting ores, it is plain that the one or the other of these weights, when used *alone*, will record the *weight;* or, if the self-calculating mode is used, as fully described at page 219, under heading 4, its value in dollars per ton, etc.

If carefully made, this beam and such weights are sufficiently exact for all practical working purposes.

The one alluded to weighed as close to the truth as most expensive balances will do. I was somewhat surprised to find that the buttons, when checked, some months after, by a finely finished balance, were found sufficiently near for even commercial purposes. A full set of weights may be made by the same beam, if preferred, as all you have to do is to make from these four units of weight, either by the rider action, or from themselves severally placed in the pan, as follows. Carefully balance the lever, and first, with the weight marked 1 in the one pan, weigh an *equal quantity* of any suitable substance in the other, when the sum of both will serve for making weight 2; again, this 2 and 1 will make the weight 3; and the 3, with the 2 and the 1, will make a 6; and so for the rest of the series, being mindful to always keep to the one pan in making the weights, and in weighing the sample and button, so that no error may arise because of unequal lengths of the ends of the lever.

The weights may be now corrected to agree with each other, by commencing with the smallest, and ranging upwards by aggregations.

By the way, few sets of weights purchased at high prices will bear this test, when made on a delicate balance.

To lessen their weight in a safe manner, you must have perseverance; and the best way that I have found is that of patiently grinding them, on a perfectly dry and slowly fretting stone, and measuring the loss by counting the number or length of equally pressed rubs thereon. There is little diffi-

culty in making very slow progress; but, to become more expert, rapid, and at the same time sufficiently exact, is quite a business in itself.

4. Assaying of Copper by Machine.—If the sample is a sulphuret, it must be roasted in a small crucible, either by being placed transversely in the cupola furnace (as shown at page 266, Cut 25), or vertically within the furnace, which is fixed by being filled with small pieces of charcoal placed under and around the crucible, kindled and regulated by the flames from the four lamps, as blown before the blow-pipe. If not a sulphuret, it must not be roasted.

A. Balance the main lever to the line on the cross lever, by weight A; then, after carefully removing A, place weight B in one end of the scale scoop, and sufficient intimately mixed, pulverized ore in the other end, until the lever returns to balance to line on cross lever, and transfer it to the crucible, for being roasted at a red heat, with twice its weight of charcoal powder, during continual stirring for ten or fifteen minutes, until no sulphurous smell is evolved; being careful to so regulate the heat that the sample shall neither partially nor wholly agglutinate. If the roasting has not ceased to sublime off all smell of sulphur, more charcoal powder must be added, and the roasting be continued.

B 1. Prepare charcoal, flux, and paper, as described under headings D, E, and F, at page 312, for common blow-pipe, but with everything twice the size; and, after taking off the rings in the front of the machine, hold the charcoal in the left hand, and proceed with the smelting of the assay as there directed.

B 2. Take a piece of strong letter-paper, two inches square, which moisten with water, and plaster it over with soap to about one-fourth the weight of the ore; next sprinkle the ore over this wet soap, and then, with the same weight of carbonate of soda as of the ore, roll it into a roundish ball.

C. Smelt this for ten minutes, on one of the machine's charcoal or composition supports, closely covered down by

another piece of suspended charcoal (as shown by the spring-fingers of Cut 15, page 138), taking great care that the whole yellow flames shall steadily cover the sample, with their full reducing influence, the whole time. Care should be taken to avoid any excess of blast, by blowing very gently and continuously, under a low head of water in the column.

D. Remove this mass of slag and ore from the coal, and carefully pulverize it in the mortar, without losing any metal or slag.

E. Plaster another similar paper with soap, and sprinkle this powdered slag and the metallic coarse copper thereon; but, instead of carbonate of soda, with about half the quantity of borax; roll it up, and smelt as before, for eight minutes, after the mass becomes molten.

F. Pulverize the assay carefully by a few blows with a hammer, between cloth or paper, and balance the one or more buttons for per thousandths, on the calculating lever, using one of the weights marked X 4, X 3, or X 2; and, for percentage, take off one figure from the right-hand side of the thousandths.

If the copper is not sufficiently fine, re-smelt it with its weight of borax for some four minutes.

Minute quantities of copper may be collected from slag much easier after pulverization, by the water method described at page 152. This should be always resorted to as a means for ascertaining if more metal is concealed in the slag, besides the large button.

5. Assaying of Copper by Water Concentration, from the Natural Constitutional Ratio, or Metallic Percentage of the Particular Kind of Dried Residue.—Most of the large and lasting copper mines produce somewhat of a general average of particular kinds or constitutions of ores, that, having similar elemental equivalent percentages, can be calculated very closely for metal from the proportions their dried residues bear to the total weight of the whole samples taken; or by comparing, with tables of notes made, the one time with another, against corresponding fire assays, as pre-

viously alluded to under the assays by water of lead and antimony.

A. Yellow Sulphuret of Copper—Can be most readily assayed in this way, when concentrated with water, as described at page 130, and dried as directed at page 293.

The weight of metallic copper is then ascertained by multiplying this weight of sulphuret by the decimals .346 for actual quantity, and dividing by 3 for the crucible result.

B. Treat as by "A" for weight of sulphuret, and multiply by your own tabular number, as found by records from previous crucible assays, made for commercial purposes.

C. The Bell Metal Yellow, and Gray Sulphurets of Copper—May be treated by water, dried, and weighed for percentage of such; but, as they are more subject to variations by accidental ingredients, as well as by difference of constitution, the multiple for each particular kind of ore found in each mine, vein, or parts of the veins, should be valued by being multiplied by the proper decimals, as previously ascertained by crucible or humid assays.

D. The Green Carbonate of Copper—May be concentrated by water, dried, and multiplied by .72 for percentage of oxide of copper, and by .575 for metal.

E. The Blue Carbonate of Copper—May be treated as under "D," and multiplied by .69 for oxide of copper, or by .551 for metal.

F. The Red Oxide of Copper—May be computed for metallic copper by multiplying its weight by .888.

G. The Black Oxide of Copper—Is somewhat rare, and being formed in *irregular nests* in the shallow sections of veins, from the decomposition of the other ores, can be seldom valued by this means.

The last two ores of copper—the red and black oxides—will not stand much water-washing; and the results cannot be relied on, even when compared to tabulated crucible assays.*

* *For such dry samples*, and even *for all others*, another ready means may be resorted to for closely approximating to the quantity of metal that can be

The easiest and best means for obtaining your multiplier for water assays is by making collateral water assays of samples that are being worked by crucible, when you can obtain the decimal multipliers by dividing the weight of the button of copper by the weight of the concentrated and dried residue; thus, if an assay from 100 grains of carbonate ore by crucible realized 55.1 of metal, you will, by dividing the 55.1 by 100, obtain .551 for the multiplier; and this rule will apply for *all quantities* in the same manner; for say that 100, or any other number of grains, is taken for the assay, and, after concentration, it is reduced to say 15 grains of pure mineral, and that this, or another similar *quantity* and *quality*, is also taken, so as to be assayed by crucible, which may be supposed to yield 12 grains of pure copper: now 12, divided by 15, will, of course, provide the multiplier for this constitutional quality of mineral. Thus 12, divided by 15, will be equal to .8, and the concentrated weight of 15, multiplied by .8, will equal 12, and serve for future practical approximations.

6. THE HUMID ASSAY OF COPPER.—It is sometimes more convenient, and always more economical, to assay copper by acid process than by crucible; and as it happens also to be within the reach of the careful amateur (although he may know but little, or even nothing, of chemistry), I have endeavored, by first oxidizing the sulphurous ores by the comprehensive chemical action of fire, and by selection of that most simple and effective means known as the "Swedish method," to make it not only most efficient for the various constitutions of ores, but subservient for all purposes, and within the ready means of all men, by extemporization of the necessary apparatus for its accomplishment.

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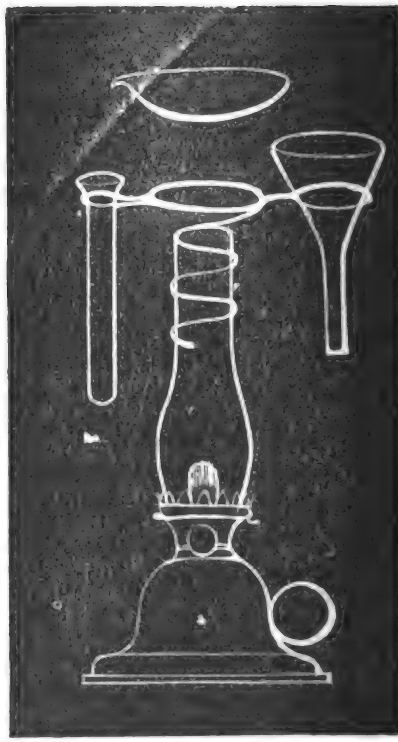
obtained from an *unmixed* or regular ore, when invariably sifted through a sieve of similar fineness, as follows.

Make notes of the percentage of metal realized from *your particular ores*, as assayed by crucible, from time to time, which table in one column; whilst, at the same time, you weigh a measured quautity, and table this corresponding weight in an opposing column, and the one may be then known from the other, on future occasions.

A common deep yeast-powder box is well suited for this purpose, which may be first balanced, and the quantity then measured and struck off by a straight-edge; the balance weight being kept for future use as such.

A. Weigh a carefully averaged sample of say 50 grains of the finely pulverized and intimately mixed dried ore, which roast as under the German assay, if necessary, and then place it in a thin porcelain dish, like that seen over the naphtha lamp (Cut 32), or in a saucer or cup; now just cover this with hydrochloric acid (muriatic), and then place it over the chimney of the lamp on the central loop of the wire that has been twisted around and over its glass chimney, and carefully evaporate it *almost to dryness*, during continual stirring.

Cut 32.



B. From twenty to thirty drops of strong sulphuric acid must now be added, when it must be again boiled until strong fumes of sulphuric acid begin to arise therefrom, when the dish, saucer, or cup, must be supplied with water to about six times the volume of its contents, and kept in a warm position for about an hour, until all the sulphate of copper formed has been dissolved into the solution.

C. Filter this solution into a basin, through the regular filtering paper and funnel (as shown by Cut 32), or through blotting paper and a bottle, made as a substitute for a funnel, in the manner described at page 267 (not forgetting the sand, which prevents a hole being knocked through when the piece of glass falls under the blow from the hammer), and wash the filter through with clean water until the water ceases to have an acid taste.*

* Filters may be folded in three ways, to suit the funnel.

1. Fold the circular filter across its diameter to a half-circle, and then re-fold

D. Place a piece of clean zinc into this basin, which, on being dissolved by the acid, will rapidly precipitate metallic copper from the solution, until the latter entirely loses its greenish blue color; this may be also known by dipping a clean and bright iron nail therein; for, if the slightest trace remain, the iron will become coated with metallic copper.

E. The undissolved zinc must now be taken out from the liquor, and the adhering copper washed back therein.

F. Carefully pour off the solution, well wash the copper with clean water, dry safely over the sauce-pan (as shown by Cut 28, at page 293), or, with greater speed and risk, over the lamp (Cut 32), by judgment of heat, as regulated by side-screw.

G. Multiply the weight in grains of this perfectly dry copper by 2, for its percentage of copper.

H. This may be smelted in a white-hot crucible, with its weight of borax, for five minutes, if a perfectly pure button of copper is desired.

I. Twenty grains may be thus treated in the wet way, and the copper smelted into a button, with borax, before the machine, where a furnace is not alight or at hand.

This method, *thus finished* by either means, is more easily and satisfactorily accomplished than by fire alone.

The residue of the ore that lies above the filter should be examined, so as to be certain that the acids have completely extracted all the copper from the quartz or other gangue.

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to a quarter-circle; take three thicknesses of the paper between the finger and thumb of the right hand, and one thickness in the left; open out to shape, drop into the funnel, wet with water; and it is ready for use.

2. Fold into half, and quarter, as before; then again to the eighth of the circle; and, when opened out to shape, with the three thicknesses of paper opposite each other, it may be dropped into the funnel, and wetted for use as before.

3. *By rule of thumb.* Lay the unformed filter over the funnel; press the center down with the flat part of the left thumb, and fold the corrugated sides down to suit the funnel. Water as before, and it is ready for use.

CHAPTER XI.

ASSAYING OF TIN.

1. By Water and Acid.—Tin is invariably obtained from its oxide, which has the several remarkable properties of very high specific gravity; peculiar compactness and cohesion of its disintegrated fragments; offering remarkable resistance to the pestle, as well as to currents of water; never found chemically combined in constitutional mixtures with other minerals; it is unaffected by a red heat; and is completely insoluble in acids and ammonia.

There is one mineral that is occasionally found associated with tin, which sometimes deceives the miner, who relies implicitly on concentration by water, subsequent roasting, bruising, and ridding it from all gangue by re-washing away in the water the impalpable oxide of iron, etc., thus produced; it is wolfram (or the tungstate of iron), which, by its superior weight, and resistance both to fire and pestle, still keeps company with tin-stone, which it closely resembles in many other general characteristics, *excepting that it is partially soluble in acids;* as the residue of tungstic acid is in ammonia.

A. Having this fact in continual remembrance, concentrate 100 grains in the manner that has been fully described at page 130, in Chapter III, on the "Qualitative Discrimination of Minerals by Water Concentrations."

Roast the concentrated sample, at a red heat, for a half-hour, with occasional stirring; pulverize to a fine state of division, and wash away the oxidized iron with further concentration by water, until the oxide of tin, which withstands this wash, alone remains.

If wolfram is absent, it may be then dried and weighed for value.

B. If wolfram is present (and strange ores should be always tested), the roasted sample should be transferred to a suitable porcelain vessel, and about twice its volume of "aqua regia" added thereto (which is a mixture of say three parts of hydro-chloric acid (muriatic) with one part of nitric acid), and boiled for a half-hour over the wired lamp (as shown by Cut 32, page 324). After it becomes cold, it is then well washed with water, until the *escaping water* ceases to have *an acid taste.*

All have now passed away in water and acid solutions, save the oxide of tin and the still insoluble residue of tungstic acid, which resulted from the decomposition of the tungstate of iron, and this must be now removed by addition of a little ammonia, aided by more gentle warmth and occasional stirring, for about an hour, when it may be again washed and concentrated by water, to remove all adhesion of foreign matter, and any silica that may have been released during the decomposition of the tungstate of iron ore.

It is always advisable to take advantage of the oxide of tin's insolubility in these solvents, whether this "wolfram" is present or not, for they also serve to remove the last adhering traces of other impurities; and, when properly conducted, roasting may be frequently dispensed with.

This heavy, insoluble, water-resisting residue of oxide of tin, being thus washed perfectly clean from the solvent and silica, may be dried as directed at page 293 (Cut 28); or over a suitably wired lamp (similar to Cut 32, page 324), and weighed. The weight *in grains* will be the percentage of this oxide, which is commercially known as "black tin;" and this, being multiplied by the decimals .7838, will give the actual percentage of metallic or "white tin."

If the sample is first roasted, and the assay is thus completed by water-washing, acids, and ammonia, no better nor safer means need be used for the estimation of tin ores.

If the metallic tin is desired as an actual button, this concentrated oxide may be reduced by smelting with fluxes, after either of the following methods, by crucible, machine, or common blow-pipe.

2. Assaying of Tin by Crucible.—In assaying tin by any of the fire methods, it must be also remembered that silica (or quartz) interferes so very much with the effectual performance of the assay, by strong affinity, that accuracy cannot be even approached, when they are both present; so that it is not only the better way to first concentrate a large quantity by acids, water, and ammonia, as above, but it is an *absolute necessity* to do so, when even an approach to accuracy is desirable. To more fully impress this on the reader's mind, I may state that if an assay be made from a sample of 100 grains of ore, composed of 80 grains of tin oxide and but 20 grains of quartz, under the superior reducing powers of black flux, in consequence of this quantity of quartz being present, only *eighty per cent. of its quantity of metallic tin will be realized;* and, if the sample contained 20 grains of tin and 80 grains of quartz, *that no button of metallic tin would be obtained.*

The more consistent way is therefore to first remove these deleterious portions from the sample by water-washing, as described under the first heading, at page 326, *and to obtain the button by one of the following modes for fluxed smelting, the best being those first named.*

A. Intimately mix this concentrated pure oxide of tin with its weight of an *equal mixture* of cyanide of potassium and carbonate of soda (as 14 grains of oxide of tin, 7 grains of cyanide, and 7 grains of the carbonate); transfer it with a scoop into a red-hot crucible; raise the heat to whiteness as quickly as possible, and after the mass has become perfectly fluid, which it will be in about ten minutes, it must be removed; the button may be removed, as soon as it is cold, by breaking the crucible; cleaned from slag, and weighed.

B. First concentrate to the pure oxide of tin, as under the first heading, page 326, and place this dried residue, without any flux, in a plumbago crucible (or a clay crucible, lined with powdered graphite or charcoal, will answer the same purpose), and closely shut down the cover (or the broken bottom of another crucible) with tenacious fire-clay, in an air-tight manner. The crucible is then carefully removed to the fire, and gradually heated to redness; and

then the heat should be more speedily raised to white, when the crucible may be again as carefully removed from the fire, without starting the cover.

When quite cold, the button of tin may be removed, as before, unless the metal is scattered into several buttons, when they should be collected in the manner described at page 152, by pulverization, water treatment, drying, etc.

C. Take of the pure oxide, that has been treated by water, acid, and ammonia concentration, as under the first heading, page 327; and to this sample of oxide add three-fourths of its weight of carbonate of soda, one-fourth of its weight of cream of tartar (which is also called argol or tartar), and about one-tenth of its weight of lime. Select a crucible that will hold about thrice this quantity, and, after these are intimately mixed, they must be placed therein, and covered first by a thin layer of carbonate of soda, and lastly by a teaspoonful of borax glass, or common window-glass. Transfer the crucible to the fire, and warm it very slowly to, and keep it at, a low red heat, for some fifteen minutes; and after increasing the heat to bright red, as soon as the sample is in a proper molten condition, it may be withdrawn and simultaneously swayed by a small circular motion, to wash the smaller globules from the side of the vessel, that they may be precipitated to the bottom by a gentle tap of the crucible on its resting-place, into the one button, which may be extracted, when cold, by breaking the crucible, etc.

D. The ordinary Cornish mode, *for similar reasons to that of the copper assay*, is conducted somewhat as follows. Two ounces of the water-concentrated ore, after being mixed with about a half-ounce of "culm" (a kind of anthracite coal), is transferred to a red-hot crucible, which is increased to white heat, and, when the contents fuse stubbornly, a little fluor spar is sometimes added thereto. In about twenty minutes, the crucible is withdrawn, and its contents are poured into a small iron mould. When cold, it is pulverized in a mortar, and the metal is concentrated by water on a concaved shovel, gently dried over the fire, and weighed.

E. The slags from smelting furnaces, which contain a small percentage of tin, associated with silica and tungstic

acid, cannot be *actually* assayed by fire; but they may be smelted with iron, which has a still stronger affinity for silica than tin has, and consequently the tin, being thus displaced from the slag, is then reduced to a metallic alloy with some of the iron, which can be then more easily analyzed by the humid method, as described under the fifth heading.

This preliminary and partial auxiliary assay is performed in the following manner.

Take as large a quantity of this generally poor slag as your crucible will treat properly; mix therewith half its weight of the oxide of iron (the scales of oxide that fall from the blacksmith's anvil will serve for this purpose), one-fourth its weight of powdered fluor spar, and one-fourth its weight of charcoal powder. Place this in a covered Cornish crucible (as that shown by Cut 29, at page 303). Gradually increase the fire, and keep the crucible at a low red heat for some twenty minutes; then increase the temperature to white heat, and, after it has been in that condition for about thirty minutes, it may be withdrawn, and the button of alloy analyzed as directed under the fifth heading, for humid assay of such buttons.

3. Assaying of Tin by the "Wee Pet" Machine.—Concentrate by humid method, as recommended for crucible assay, and then treat, with cyanide of potassium and carbonate of soda, the same quantity from weight B, in the same manner as stated at page 291, under the second heading, for the assay of both lead and antimony, under subheading H, at page 292.

4. Assaying of Tin by Common Blow-pipe.—The oxide of tin cannot be treated with any great degree of accuracy before the blow-pipe; but the following methods are perhaps more exacting than any others, and are at least substantial collateral proofs that the residue produced by the system of humid solution and concentration, fully explained at page 326, is really tin.

A. Take one grain of the supposed oxide of tin, and treat it in the covered shaft-furnace, as heated through the blast tunnel, in the same manner as the copper assay

described at page 312, under headings F and G, but with these differences: that one grain of cyanide of potassium must be added to the fluxes there named, and that it is directly smelted in the one operation, which should be completed in from eight to ten minutes.

B. Take one grain of the supposed pure oxide, which treat in exactly the same manner as directed under the third heading, and sub-heading B, page 292, for assay of both lead and antimony, when in alloyed condition.

5. The Humid Assay of Tin and Iron Alloys, as Prepared by Fluxed Fusion in Crucible, under Sub-heading E, at Page 329; the Buttons Being Especially Obtained for this Purpose from the Siliceous and Tungstic Slags of Smelting Furnaces.—As some miners may, in far remote regions, have to smelt their tin ores into metals, it is imperatively necessary that they should have a means for estimation of the amount of tin that remains unreduced in their slags. Although the crucible greatly facilitates the humid assay in this instance, by causing iron to re-place the tin in the slag, and to form also a simple alloy of metallic iron and tin, it will not thoroughly accomplish the assay; so that, as this button of alloy must be treated by some humid process, I suggest the following, as being the one that is most reliable, and yet comparatively easy to accomplish, in such fixed establishments.

This button of alloy, as obtained from the slag by fusion, process E, page 329, must be brushed thoroughly clean, then dissolved in a boiling mixture of strong hydro-chloric acid (muriatic), three parts, to one part of water, and filtered into an open-mouthed vessel, as a glass tumbler or basin.*

The tin must be now precipitated in the following manner, by sulphide of hydrogen gas, which may be made expressly for the purpose, in the apparatus illustrated by Cut 33.

The cut explains itself, as to general arrangement of parts.

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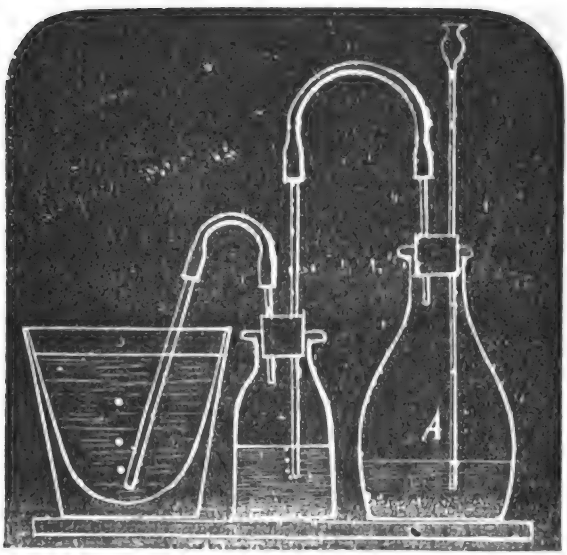
* *Before the solution is filtered*, it may be tested by a piece of bright metallic iron, for copper, etc., etc., which should also *precipitate* any excess of such metals from the solution, when the *iron of the alloy* was insufficient for *this effect* (which will, however, be very unusual).

The tubes may be all made of glass, or glass and india-rubber combined, or of quarter-inch india-rubber tubes alone. It may be also ordered as "sulphide of hydrogen apparatus," and supplied in condition for immediate use.

The bottle, A, is first placed on a suitable board, and supplied with about an ounce of sulphuret of iron; the small bottle is half-filled with water; then, after the corks are drilled and tubed as shown, they are moistened and inserted, in an air-tight manner, into the necks of the bottles, with the last bent tube into and near the bottom of a glass tumbler that contains the solution, just as shown. The bed-plate or tray that

Cut 33.



contains the vessels is now moved out-doors, or to a chimney (as this gas is very disagreeable and poisonous), and the bottle, A, is first supplied, by way of the long funnel tube, with sufficient water to cover the sulphide of iron, and then with concentrated sulphuric acid, when the sulphide of hydrogen gas is formed, and being prevented, by the liquid which rises in the tube, from direct escape, it passes first through the water in the small bottle, where it is cleansed from any mechanical substance, and thence through the solution, and precipitates the tin in a yellowish brown sulphide form, which

becomes darker on exposure to air. The gas should be passed through until the solution smells very strongly thereof, when moved away from the supplying pipe.

The solution may be now carefully poured off from the precipitated sulphide of tin, and, after the precipitate has been well washed by water, it may be gently roasted in a platinum or a smooth French crucible, at a low red heat, until all sulphurous smell ceases; then the cold contents may either be re-heated with a little carbonate of ammonia, and, when cold, weighed as oxide, and then multiplied by the decimals .7838 for metallic tin; or be actually reduced to metallic tin, by fusion with carbonate of soda and cyanide of potassium, under either of the fire methods that may be found most convenient for the occasion.

CHAPTER XII.

ASSAYING OF MERCURY.

There are many ways by which mercury can be assayed, both by fire and humid methods; and three may be more particularly commended to the miner, for his practical purposes.

1. Assaying Mercury by Crucible or Scorifier.—Nearly all the mercury of commerce is derived from cinnabar, and it is generally found tolerably free from other volatile substances; so that it may be estimated sufficiently near for practical purposes, by *roasting* say 100 grains of unfluxed ore in a suitable vessel (as a scorifier, roasting-cup, smooth French crucible, or platinum crucible), *at a red heat*, for about fifteen minutes, when the *difference* of the weights of the *vessel, before and after roasting*—as both sulphur and mercury are thus entirely volatilized—will equal the weight of the ore.

This loss of weight, multiplied by the decimals .8621, will give the theoretical quantity of metallic mercury; and, by obtaining your own *real working multiplier*, the quantity that can be obtained in practice.

2. Assaying Mercury by Retorting the Fluxed Sample.—Mercury can be accurately assayed, in whatsoever form it may exist, by being heated to redness in a closely covered iron retort, similar to those used by amalgamators, with the following fluxes, etc.

A. To every 100 parts (in weight) of the sample of ore, add the *quantity stated* of *one* of the following substances: Iron or copper filings, 30 parts; or of black flux, 60 parts; or of an equal mixture of powdered charcoal and lime, 70

parts; these must be first very intimately mixed together, and then covered with a thin layer of the same flux.

Gradually heat to low red, then to red, where keep it for some ten minutes, until mercury ceases to come through the neck of the retort, and, after lightly tapping the neck of the retort, weigh the metallic mercury for percentage.

B. Take 100 grains of ore, flux and mix as above, and place the mixture in a thin Florence flask (as a salad oil flask), and warm the bulb to red heat over a charcoal fire for twenty minutes, keeping the long neck almost horizontal, and quite cold by a watered rag, so that all the mercury may deposit in the neck. Remove the rag, and, when the bottle is cold, file the neck round just below the mercury, and break it off from the bulb; now slowly dry it at about 150° of heat; weigh the mercury and glass, then free it from the mercury, and re-weigh the glass; the difference will be the weight and percentage of the mercury.

C. Treat 10 grains of ore in a long test tube, in a similar manner as under the last sub-heading, B, and weigh; when each tenth grain will be the unit of percentage.

3. Assaying Metallic Mercury by Water-washing.—First wash 100 grains of the sample in a cupful of clean water, then pour the water away; then, after repeating this twice or thrice, half-fill with water, and dissolve about 10 grains of cyanide of potassium therein, and, after again washing the sample with a circular sway in this liquor, it may be warmed, and allowed to remain until cold.

Now concentrate and free the mercury from all the lighter gangue, by water-washing it over the margin; then gently dry the mercury over warm water, and weigh in a balanced cup for percentage. If cinnabar should be also present, the difference of this weight and that of either of the assays made under the second heading, by letters A, B, and C, will give the percentage of mercury that was contained in the ore.

CHAPTER XIII.

ASSAYING OF IRON.

Iron cannot be estimated by fire with great accuracy, but can be approximated sufficiently near for all practical purposes.

1. By Crucible.—Here, again, the chemistry of the assay may be very much simplified, as well as the result regulated and produce enhanced, by the preliminary roasting of all its ores, into the one constitutional form of peroxide.

A. Take two samples, of 100 grains each, of the finely pulverized and carefully averaged ore, and roast them in scorifiers for at least one hour, during frequent stirring, in a muffle, at a red heat, until it has a red, earthy appearance.

B. Take two London, Cornish, or French crucibles, of about five inches high, which line with charcoal, by placing smaller and similar crucibles within, and ramming moistened charcoal between the vessels.

The inner crucibles may be withdrawn, by suitable jostling and twisting motions; and, when *slowly dried*, they are ready for use.

C. Intimately mix this roasted (100 grains) sample with 100 grains of one of the carbonates of lime (as chalk, marble, or calc spar), with 100 grains of common window glass, that is free from lead, and with one part of charcoal, all finely pulverized.

D. Transfer these mixtures to the duplicate charcoal-lined crucibles, and, after filling the remaining spaces with small pieces of charcoal, the lids must be luted on with fire-clay.

E. Place the crucibles in the furnace, and raise them

slowly to a red heat; then increase to *white heat;* and, being thus kept for full twenty minutes, they may be withdrawn, and gently tapped on the top of the furnace, to settle the small floating buttons into the one large button at the bottom; the buttons may be removed and weighed, when cold, for percentage of iron.

If the buttons are still separated, they may be collected from the pulverized slag by magnet, or by water-washing, drying, etc., as described at pages 152 and 153.

The heavier of the two buttons should be taken, as being nearer to the true result from *properly averaged* samples.

The metal should not be so brittle as to break into powder under the hammer; but, rather, to flatten slightly in a semi-ductile manner, then crack around the edges, and fracture in a similar manner to whitish cast-iron.

2. ASSAYING OF IRON BY WATER CONCENTRATION.—*Some of the more compact and slightly friable iron ores* can be assayed very closely by water concentration, and subsequent calculation, either from their *constitutional* or previously *tabulated* percentages, from the weights of their dried heavy residues; the most prominent of which are the magnetic iron ores, the carbonate of iron, common iron pyrites (bi-sulphuret), arsenical iron pyrites, and the worthless tungstate of iron.

These can be assayed by carefully concentrating 100 grains of ore, as pulverized and averaged by the method fully described in Chapter I (pages 120, 121, and 122), and multiplying the weight of the dried residues by either their constitutional or tabulated *practical* percentages, and dividing by 100.

There are others, which include all that pulverize freely to a red and impalpable powder, that *cannot be thus assayed* to even *an approximate degree* of accuracy; for the *whole* may be thus passed away in mechanical solution, by continued pulverization, and additions of water.

3. APPROXIMATE ASSAY OF IRON, AS GOVERNED BY VOLUME AND WEIGHT, FROM TABULATED COMPARISONS WITH PERCENTAGES OF PREVIOUSLY MADE FIRE OR HUMID ASSAYS.—*The last named friable ores that cannot be assayed by water, as well as all*

the other ores, that can be, may be estimated for practical working purposes, on the peculiar and particular ores of the same mine, for the ordinary manipulative purpose, in the following ever-ready and costless manner.

Record every assay that you have occasion to make or obtain, by fire or acids, in working on the large scale, in its proper place, into one *long column*, that has a line for each profitable unit of percentage; and, for *every assay thus actually made*, take one *measure* of the ore (say a tin yeast-box, or a coverless tin flour-dredge, which has been balanced by a suitable balance-weight kept for the purpose), striking it off straight across over the top, and record *its weight* in the opposite *corresponding unit* of *another* column, for *future reference;* and in a short time you will have a sufficient series within the required range of percentage.

The ore must, as a matter of necessity, for this and ordinary practice, be passed through the same fine sieve, and it will be found more accurate to settle down the powdered ore by tapping lightly on the sides of the vessel until it will receive no more, than merely filling and striking off without it; but a third column may be added, to show the weight of both results, for better comparison.

The ore must also be perfectly dry, at all times alike, for the fire, the humid, and measure estimations.

The high percentage of the iron ores, the rare and trifling presence of other metallic minerals, and comparatively great difference of the specific gravities of the ore and gangue, together with the difficulty, uncertainty, and expense of making either the humid or fire assay, render this mode much more accurate and valuable for the iron than for most other assays. Which fire or wet assay might be made by any distant assayer, for this one purpose, for your equivalent guide, when repeated by both measure and weight, as required.

Indeed, it would be quite a desideratum for the iron miner, if it did no more than indicate by one example, in this prompt manner, the zero of percentage that should not be shipped for the smelting furnace, or the market.

4. The Humid Assay of Iron—Is greatly simplified and facilitated by a preliminary roasting of about an hour, at a

full red heat, which (by volatilization) bring the ores that contain the most refractory elements for humid treatment into the same state as the other natural ores, which yield more readily to the action of acids.

The following is perhaps, under all conditions, as easy and safe a means as can be employed by the miner, who is not well versed in chemical reactions and manipulations, and supplied with the numerous, complicated, and expensive facilities that would be otherwise required.

A. Roast 50 grains of averaged, finely powdered ore in a well chalked cup, or crucible; and, after scraping the whole of the ore from the roasting-cup, it should be again pulverized and gently boiled for a half-hour, with about six times its volume of "aqua regia," in a small glass flask or porcelain dish, placed on the wire ring over the lamp (as shown at page 324, Cut 32), so regulating the heat that no liquor shall be projected over the vessel by excessive ebullition.

B. Allow it to stand and cool down for a few minutes, until the liquor becomes clear, by the settlement of the solid portion, and carefully pour it into some other suitable vessel, that has also a pouring lip; then *treat the solid residue with another quantity of the acids in the same manner*, and unite the two liquors into the one basin.

C. This solution must be now completely evaporated by boiling; after which, the soluble parts of the dried residue must be again dissolved, in about the same quantity of an equal mixture of hydro-chloric acid and water.

D. This is then filtered, and, after the two insoluble residues are placed (or, rather, washed) upon the filter, it is well washed by additional water, to pass the last relics of the acid through into the solution, so as to obtain all the iron, before it is put aside for precipitation.

E. It may now be warmed, when, by adding an excess of ammonia, the iron, with the alumina (that will also be very often found present) can be precipitated.*

The alumina may be separated from the sesqui-oxide of

* The warming is not imperatively necessary, but will, by lessening the gelatinous action, greatly facilitate the subsequent filtration, etc.

iron, after they have been first well washed with water, by being boiled with caustic potassa for some time, in a thin porcelain dish, over the lamp, as in the first acid stage, which dissolves out the alumina, leaving the oxide of iron, which may be now well washed with water, perfectly dried at 212° (over the sauce-pan, as previously described, if you have no more usual means); then ignited, to burn off all the surplus weight of paper over a clean saucer by the aid of a match, and weighed.

This weight, multiplied by .70, will be the percentage of metallic iron.

G. If it be desirable to ascertain the percentage of the insoluble portion of silica, etc., the weight thereof will show it, after its filter has been *thoroughly dried*, and removed therefrom by complete ignition.

H. So the lime and magnesia can be known (to provide for more exact fluxing), by first adding to the original ammoniacal solution, from whence the iron was precipitated, sal-ammoniac (chloride of ammonia), which prevents magnesia from being precipitated; and then adding oxalate of ammonia, to precipitate the lime as oxalate of lime, which may be changed to carbonate of lime, as it was in the rock, and for flux, by being warmed to a red heat, with a little slightly moistened carbonate of ammonia; and then simply weighed as such, for percentage.

I. The magnesia can be now precipitated from the solution by addition thereto of phosphate of soda, which, after being washed, dried, ignited (by a match, to burn off the weight of paper), and weighed, may be closely approximated for magnesia by multiplying by the decimal .36.

These re-agents should be in liquid state, as dissolved in water, and be filtered through clean and pure filters into the solution that is being analyzed.

CHAPTER XIV.

ASSAYING OF MANGANESE AND ZINC.

1. By Crucible.—The pulverized oxides of manganese may be reduced into metal by being mixed with oil into a paste or ball, and subjected, for some twenty minutes, to the greatest possible heat that can be obtained by the furnace.

The metal itself is, however, of no value, either for use or ornament, as it is so very infusible, hard, and brittle; of grayish white color, which tarnishes quickly in air, and is rapidly oxidized when heated. In one of its mineral conditions, that of peroxide, it is of great use in the laboratory, in the arts, and in metallurgy, and the quantity of oxygen that can be extracted therefrom is consequently its best measure for useful value.

2. Estimation of the Oxygen that is Free for Extraction, by Heating to Redness in the Muffle.

A. Warm 100 grains of the averaged, finely powdered ore, in a scorifier, or roasting-cup, for a half an hour, in a muffle, at a *red heat;* remove it therefrom, and weigh, after it is quite cold, as this heat has caused the removal of *the quarter* of its *real quantity* of oxygen, and one-half of its *disposable quantity* for the production of chlorine gas; and as the pure peroxide of manganese would, when thus treated, release 9.25 *per cent.* of oxygen, it follows that the loss of weight sustained measures its ratio of value. For example, if this loss is say 6 grains, then it stands: as 9.5 is to 6, so is 100 to its comparative percentage of value, as compared with the pure oxide; or, 100 multiplied by 6 and divided by 9.5, equals its percentage value of 63.1.

In this mode of assay, there must not be any native metals, etc., present, which would increase the weight by oxidation;

nor any compounds that would undergo changes at red heat; neither of which are very common in this ore. *This method is but an approximation.*

B. *A white heat, applied as above, displaces one-half of the oxygen, which is all that can be realized for the practical purposes of obtaining either oxygen or chlorine gases; but this is not so readily nor surely accomplished as the quarter by red heat.*

3. Assaying the Peroxide of Manganese by Water Concentration.—The peroxide of manganese is the only valuable one of these minerals; which is black, or slightly brownish black, when powdered.

It may be concentrated by water, with trifling loss; and when free from iron, which must be first tested, it is seldom associated to any extent with the other minerals.

It may be concentrated in the manner of lead, antimony, tin, copper, etc., dried, and weighed for percentage of weight.

The pure peroxide of manganese contains of oxygen, 37 per cent., 18.5 of which is, as stated, the useful half, which alone can be extracted in practical requirements; so that the concentrated weight being ascertained, the ratio of percentage may be also known by calculation, as before.

The multiplier may be made for your own mine, as in the other instances; or a double-column table may be founded from the next following correct chemical method.

4. The Humid Assay of the Peroxide of Manganese.—The following method is sufficiently accurate for all the purposes of the metallurgist, and can be performed, with but little difficulty, by an amateur.

A. Thoroughly clean the sulphide of hydrogen apparatus (shown by Cut 33, at page 332), and place 100 grains of the manganese ore into flask A; after stopping down the vessels perfectly gas-tight, with the tubed corks, as shown, and nearly filling the receiving tumbler with lime water, pour down the long funnel tube of vessel A about 600 grains of hydro-chloric acid (muriatic) upon the ore, and apply gentle warmth from a lamp (or by placing bottle A in a small saucepan of cold water, and then warming it over a fire.

The chlorine gas thus formed passes over into the second bottle, and thence into the tumbler (or any other larger vessel), and through the lime water, and, having strong affinity for the lime, it instantly forms a chloride therewith, from which the quantity of chlorine can be readily ascertained by simple calculation.

It will be necessary to have an excess of lime water in the precipitating tumbler, and, before finishing the analysis, to drive over all the chlorine gas into the lime water, by pouring water down the long tube of A, so as to first fill this vessel with watered acid, and then to expel the gas from the second vessel, by blowing into the funnel tube just sufficient air to force over the thus diluted acid therein, until this bottle also becomes freed from the remaining chlorine gas. The lower end of the discharge tube in the second bottle should be close up under the cork.

Care must be taken that neither the breath nor the diluted hydro-chloric acid shall pass over during this expulsion of chlorine gas, as the former would form carbonate of lime, and the latter chloride of lime, which would cause an error in the result.

The solution in the tumbler may now be filtered, so as to collect the chloride of lime on a *previously dried and balanced filter*, which must be dried at 212°, in a suitable water oven, or as directed at page 293, over a sauce-pan of boiling water.

The 100 grains of pure oxide of manganese, when thus treated, release from the acid about 75 of chlorine gas, which, by uniting in this tangible manner with lime, form 117.2 of the chloride of lime; and, this dried weight being known, the weight or percentage of the gas that has been produced from the ore may also be known, as follows.

If the weight of the chloride of lime produced from 100 grains of ore was say 58.6, then it would be, as 117.2 is to 75, so is your weight of 58.6 to the weight of chlorine gas realized from your ore, and its ratio of percentage value in practice. Or, $\frac{75 \times 58.6}{117.2} = 37.5$.

If you take a lesser quantity for the assay, as 50 or 20 grains, first multiply by 2 or by 5, to throw the quantity into hundredths, and still proceed to figure for value as in the preceding paragraph.

ASSAYING OF ZINC.

1. By Water Concentration.—The zinc ores may be approximated for percentage by water treatment in precisely the same manner as the ores of lead, antimony, copper, tin, iron, and manganese; and the weight thus obtained, being multiplied by its equivalent, or *practically ascertained* decimal number, will give the percentage of metal; and as the fire assay is tedious, uncertain, and very difficult, this will be very serviceable to the miner for the every-day purposes that are required.

2. Humid Assay of Zinc Ores.—Dissolve 100 grains (or any more convenient quantity, to suit your purpose), in four parts of hydro-chloric acid (muriatic) and one part of nitric acid, by boiling until the solution is evaporated to perfect dryness, and almost to red heat; then moisten with sulphuric or nitric acid (not hydro-chloric), gently warm, until dissolved; add water, and filter the solution into a suitable vessel for precipitation. Add a strongly alkaline *excess* of aqua ammonia, and warm, which precipitates any iron, or manganese, etc., as well as the zinc, and, when *in excess*, re-dissolves the manganese and zinc into solution, which must be again filtered, and the residue washed with a very dilute solution of ammonia, to carry through the whole of the zinc, and, if manganese is present, that also; and therefore, unless you have ascertained (as directed in Chapter VI, under that mineral's heading) that it *is not present*, you had better to be safe, and separate it from zinc, as follows, before final precipitation.

Add acetic acid to the solution, until it becomes strongly acid, which keeps the manganese in the solution whilst the zinc is being precipitated therefrom by sulphide of hydrogen gas (that must be generated in an apparatus shown by Cut 33, and described at page 332), and forced through this strongly acid solution until all the zinc is precipitated, when this sulphuret of zinc must be collected on a filter by filtration, well washed by water, and then dissolved in dilute hydro-chloric acid.

An excess of carbonate of soda must be now added to this filtered solution, until no more carbonate of zinc is deposited.

Now *dry a clean filter* at 212°, and balance or weigh it on

your scales accurately, and note its weight for deduction, if weighed; then fold it into a funnel, filter, *wash*, *dry perfectly at* 212°, and weigh.

This weight, less that of the dried filter, will be the weight of carbonate of zinc; which, being multiplied by the decimal .8, will give its percentage of metallic zinc.

There are several fire methods for assaying zinc ores; but, as none of them are even nearly exact, nor of easy execution, I have deemed it better to rely on the two humid modes which are given above, rather than describe uncertain means for manipulation.

The water treatment will be sufficient for practical purposes on the mine, and the chemical for its commercial estimation.

The method of volume and weight, previously described, may be also resorted to, for similar ores of the same vein, for the minimum percentage that will pay for extraction, so as to approximate for working purposes, as tabled from humid assay, or assays.

To ascertain the amount of gangue, it may be also roasted for several hours, at a high red heat, and weighed for loss of weight of ore, and the actual weight of the non-volatile residue of matrix.

CHAPTER XV.

ASSAYING OF COALS, AND OTHER FUELS.

1. By Ignition in a Clay or Platinum Crucible.—A good practical estimate of the quality of coals may be made by simple ignition of 100 grains in a muffle, or in any open, clear fire, for a sufficient time to consume the combustible elements, by subtracting the residue of unconsumed clinker and ash from the original weight taken, for the percentage of inflammable residue.

The characters of smoke, flame, and duration of coke, with the nature of clinker, etc., being duly noticed for quality, give additional evidence of superior or inferior quality, beyond the mere weight of carbonaceous matter present.

2. Assaying of Coals in Crucible, as Governed by Quantity of Carbon Present.—The most ready means for the estimation of a fuel is that devised by Berthier, the French chemist, which may be performed as follows.*

Care must be taken that the litharge is free from minium, and it is better to purify it by fusing in a clean crucible, at a red heat, an intimate mixture of pulverized charcoal, 3

* Dr. Ure, in the supplement to the Dictionary of Arts, Mines, and Manufactures, says:

"On subjecting this theory to the touchstone of experiment, I have found it to be entirely fallacious. Having mixed, very intimately, 10 grains of recently calcined charcoal with 1000 parts of litharge, both in fine powder, I placed the mixture in a crucible, which was so carefully covered as to be protected from all fuliginous fumes, and exposed it to distinct ignition.

"No less than 603 grains of lead were obtained; whereas, by Berthier's rule, only 340 or 346.6 were possible. On igniting a mixture of 10 grains of pulverized anthracite, from Merthyr Tydfill, with 500 grains of pure litharge, previously fused and pulverized, I obtained 380 grains of metallic lead. In a second experiment, with the same anthracite and the same litharge, I obtained 450 grains of lead; and, in a third, only 350 grains. It is therefore obvious that this method of Berthier's is altogether nugatory for ascertaining the quantity of carbon in coals, and is worse than useless in judging of the calorific qualities of different kinds of fuel."

grains, with 1000 grains of the impure litharge, which will extract the minium, and leave the litharge as it should be, when it can be pulverized and used with greater confidence.

Now unadulterated carbon will reduce from litharge 34.5 times its weight of lead; and hydrogen 103.7 times its weight of lead; so that the amount thus reduced by any fuel will give the comparative quality of the fuel.

I have found it much better, for practical purposes, to disregard the above data, and to first take 10 grains of finely pulverized coal, *of known first-class quality*, with 300 grains of litharge, most intimately mixed together, and covered by a layer of another 300 grains of litharge; then to take another 10 grains of the fuel to be assayed, and next, after being similarly prepared, they are placed side by side in a furnace, and slowly heated to redness; the heat is speedily increased to white, when they are withdrawn from the fire, and allowed to get quite cold before the buttons of lead are extracted, by breaking the crucibles.

About 20 grains of common glass powder may be first put in the bottoms of the crucibles, so as to protect the lead from the subsequent action of the litharge, and thereby produce a more compact and clean button.

If the litharge, whether pure or not, is first intimately mixed to a correct average of quality, as instructed for the preparation of an ore assay, in Chapter I, and the coals are both dried, there can be no reason why these assays of genuine coals, and that on trial, should not be an exact comparison for ratio of values; conducted, as they are, by both flux and fire, in a precisely similar manner throughout.

I have found this exactly similar comparative duplicate test, with *first-class coals*, or *charcoal*, more simple in execution, and most reliable, when the litharge has been first mixed into correct average, and no considerable excess has been used.

John Mitchell says, in his large work on Assaying, that if the commercial white lead is used, instead of the impure litharge, much closer results can be obtained. He has not, however, endorsed Ure's condemnation of Berthier's mode.

3. Assaying Coals by Common Blow-pipe, for Approximate Results, when Traveling.

A. Burn off all the inflammable ingredients of 1 grain

of the powdered coals, in the manner of roasting a copper assay (as described at page 311), and weigh the residue of clinker and ash, for percentage of useless elements; which, being deducted from the 1 grain, or the 100 parts, will give the combustible percentage. Then compare it, by another example, with good coals.

B. Take a solid stone, and cut it so that it may weigh just 1 grain, which burn *very gently* on charcoal, before the blow-pipe's flame, and weigh as before, under A.

4. Assaying Coals by Machine.

A. Proceed on the quantity as weighed by weight B, just as by common blow-pipe, under A or B, and balance, for percentage, on calculating lever.

B. Ignite and burn off, in the crucible, when placed as a muffle (as in Cut 25, page 266), similar to that of ignition in crucible, as under the first heading of this chapter.

5. The Estimation of the Sulphur Associated with Coals.—This will be found very desirable for many purposes, for it is not only disagreeable to those who have much to do with fires, but highly deleterious; as it forms sulphuric acid, and various compounds, as the products of combustion, such as the sulphides of hydrogen, ammonia, and carbon, which attack the iron or copper of steam and cooking boilers, so energetically that they are soon rendered useless; and when such coal is used for the production of illuminating gas, oil paintings, colored fabrics, and silver ware, become sadly discolored and tarnished, unless the gas manufacturers apply the proper means for purification.

The following method, given in John Mitchell's large work on Assaying, will be found very efficient for your purpose.

"*Process.*—1 part of the coal, finely pulverized, is mixed with 7 or 8 parts of nitrate of potash, and 16 parts of common salt, and 4 parts of carbonate of potash, all of which saline matters must be perfectly pure; the mixture is then placed in a platinum crucible, and gently heated. At a certain temperature, the whole ignites and burns quietly; the operation is finished when the mass is white. It must, when cold, be dissolved in water, the solution slightly acidulated by means of hydro-chloric acid, and chloride of barium added to it as long as white precipitate forms. This precipitate is sulphate of baryta, which must be collected on a filter, washed, dried, ignited, and weighed; every 116 parts of it indicate 16 of sulphur."

SECTION IV.

MINING AND ENGINEERING.

CHAPTER I.

EDUCATION OF A MINING ENGINEER.

The appellation of "Mining Engineer," being quite modern, is not very generally understood.

It embraces most of the duties of Military, Civil, and Mechanical Engineers; those of the Surveyor, Geologist, Mineralogist, Assayer, and Metallurgist, *as well as that of the Miner;* for he has to excavate all kinds of earth and rock works, etc., during his whole life-time, amidst the greatest dangers; he has to construct steam and horse roads, bridges, aqueducts, and canals; design, give drawings of, and erect machinery for, pumping, hoisting, conveying, crushing, separating, and reduction; be able to plan and supervise amalgamating, chlorinizing, smelting, and refining works, when more advantageous to smelt or refine on the mine, for the market; be sufficiently acquainted with surface and subterranean surveying to communicate, by shaft or level, to distant workings; have full practical knowledge of strata for general contract prices; of minerals, for profitable quantity over cost of extraction; and the best means of beneficiating the ores, *previous to their being reduced,* by mill, chlorination, or smelting works, *as well as during their reduction;* and be more particularly practised in mechanical engineering, and conversant with all the practical minutiæ of mechanical arrangements for developing a large mine, both above and below the surface and the water level, in the most economical manner, by

correctly positioned shafts and levels, with suitable general appliances for pumping, hoisting, tramming, stoping, timbering, ventilation, etc.

He should also be a good business man, so as to make more favorable terms with merchants, carriers, etc.

As it is imperatively necessary that any man who would be a "Mining Engineer" in this, *the proper definition of the word*, should be acquainted with these several advantages, his education must be subservient to these purposes.

Algebra, Euclid, and practical Geometry, should supplant logic, etc., so that he may be sustained by the more powerful auxiliary of sound reasoning, during his ever-varying and most difficult practical operations.

He should have, beyond the education of the Military, Civil, and Mechanical Engineers, but sufficient instructions in Geology, Mineralogy, and the chemistry of Assaying and Metallurgy, for his practical purpose; for a comprehensive study of chemistry requires more time than he has at his disposal.

His brain should be the more permanently embossed with all that is really necessary in practice, by avoidance of the crowded confusions that are produced by the cramming of the mind with every irrelevant subject.

Here must be obtained sufficient scientific intelligence, as the germ for more substantial demonstrations during his diversified practical life; to merely study high-toned, isolated theory, and despise practical application, will be most pernicious to the true interests of mining, for such men will but soar in dreamy Icarian flights, far above the stratum of ordinary usefulness, and seldom alight on *Terra-firma*, to awake to hourly duties, and will never succumb to those subterranean labors that must be performed with industrious and vigilant care, to develop profitable mines.

Although the boy may be admired for such outside, additional studies (as they will be forgotten during manhood to make room for others), the practice must be deprecated when studying for this business. As it is at this time most desirable that boys should be educated in a proper manner for this new avocation, it may not be out of place to say a few words on the subject.

In the County of Cornwall, England, which has a railway running its whole length of less than 100 miles, the one Central Mining School, after having been much opposed, was abandoned, as inapplicable for the education of boys who resided in the several mining towns. If this system worked badly there, it will be worse in this much more extensive country, with its scattered population.

Your admirable public schools, being generally at the people's doors, might be made the fountain of instruction for this one additional practical subject; their most favorable features being that they are *within reach*, and *non-exclusive.*

The boys' high school of each mining State might be made the nucleus and diffusing centre from which a mining tutor should, in addition to teaching this class at the one high school, travel occasionally through the mining towns, which have local schools, to give lectures therein on the various mining subjects.

A portable cabinet of tools and re-agents, for the assaying and analysis of the minerals, etc., etc., etc., might be either carried from school to school, or supplied to each one separately, for the occasional illustrations of the lecturer, or for the continual practice of the pupils.

"*One ounce of practice is worth a pound of theory,*" is an old but true saying, and not only true in a general sense, but absolutely imperative in the particularly difficult and dangerous business of mining; so that now commences the stern reality for the practical experience of the educated expert, who is still but a mere novice in the true art of mining.

His first steps in practice should be to learn the actual trade of the mechanical engineer, by working some three or four years in a mining foundry; then he may go out with a party to erect an engine, or other machinery, for sufficient experience in this most important part of the business.

He should now take lessons in, or study and practise, surveying.

And, lastly, go into a mine, to gain a full knowledge of all the different practical phases of this business.

Mr. J. Budge, the author of the old Cornish work on Surveying, etc., called the "Practical Miner's Guide," says:

"The qualifications necessary to constitute an accomplished miner are more

numerous and difficult of attainment than is generally imagined, even by persons deeply interested in mining affairs. * * * It is certainly highly desirable that agents who have the management of large adventures should possess a general knowledge of everything connected with the profession of a miner."

I regard that powerful lever of his avocation already alluded to, called Mechanical Engineering, as more imperatively necessary than any other, as little can be accomplished in a proper manner without it, in the extensive mining of deep sections; and it is vastly better to learn it in a direct manner, at some large mining foundry, before entering into mining operations, than to acquire knowledge at the enormous cost of continual errors, that must be otherwise most frequently committed during long experience. For, thus prepared, and starting with a full acquaintance with pumping, hoisting, tramming, crushing, stamping, roasting, amalgamating, chlorinizing, and smelting machinery, he will be enabled to design and forward his plans, by giving drawings for what he requires to be made at the foundry or on the mine. He will, moreover, be a legitimate and much superior supervisor of tradesmen, and possess the self-sufficient knowledge for laying out and erecting the necessary machinery upon the surface, as well as fixing the underground appliances in the best possible manner, for pumping, tramming, hoisting, ventilating, timbering, etc., etc., which should be planted in the strongest possible manner, as all preliminary errors of this kind, by causing continual waste, from oft-recurring accidents, will subtract from the larger profits that would otherwise accrue.

In many far-distant, mountainous, and inaccessible interior regions, where good iron ore and fuel are plentiful, it is often most advantageous to have (in addition to the usual smith's, fitter's, carpenter's, timberman's, and pitman's workshops) a smelting furnace and casting foundry, so as to repair or renew, by actual manufacture, the heavy wearing parts of the various machinery, by which much expense and loss of carriage, etc., may be saved, and transferred, to enhance the profits from large mines.

The further knowledge of rocks, minerals, and mining, must be acquired by long practical observation and experience, so as to be of any really serviceable benefit, for the working purposes of extraction and beneficiation, or for the estimation of the value of veins.

A man constituted with persevering acquisitiveness, who has industrious habits, and sufficient firmness to contend with the difficulties, dangers, and uncertainties of this avocation, can become acquainted with these necessary qualifications, both of education and practice, in from fifteen to twenty years; and, if he possesses sufficient integrity and honesty towards employers to condemn what he deems unprofitable, he is indeed worthy of his hire, and is a boon to the whole mining community.

The financial leaders of mining companies have too often disregarded their most substantial interests, in this connection; for they have shown no more discretion when selecting their superintendents than gratitude to the few honest, qualified experts, who have sought other employment, rather than waste their funds on unworthy properties, from the deplorable fact, that market gambling or swindling companies, have been more the rule than the exception. Such men, having sought to make money in this manner, neither desire advice, nor deserve sympathy; but, unfortunately, *it does not end with them*, as this capital, *properly expended*, would have fostered and established mining as a staple industry, instead of degrading it, as the rock that should be avoided; so that if mining did not infatuate more than deter, the results would have been most disastrous, as the enormous mineral resources that are even now being wrought in the Pacific States and Territories would have still remained concealed.

There are those who select with systematic caution, and mine by rule, as they would manufacture or navigate, by beacons that warn and guide them from loss, to a secure and profitable haven, where the insurance is guaranteed, under the steerage of the qualified pilot.

Nothing can be more antagonistic to the real advance of mining interests, than those twin banes, the ever-sanguine, unscrupulous "*Market miner*," and the clean-fingered, kid-gloved, Icarian notioned, fully graduated "*College expert;*" for the former, under the exonerating fosterage of swindling stock jobbers, by his shrewdly concocted mythic reports, sustains worthless mines; whilst the latter, insanely patronized by moneyed stockholders (a mere theoretical embryo of what a mining engineer should be), presumptuously engages to

superintend the most difficult operations of this preëminently extensive avocation, where all must be conducted according to the practices of tradesmen, who have been educated, by a life's experience, for this particular business.

These subordinates, having *to do the real duties* of mining, will despise a mere scientist as manager, who lacks these imperatively necessary practical qualifications; the miner will bamboozle him at every turn, in the intricate and dangerous ramifications of mining; the timberman, having the exact length of his feet, will yoke them with a pair of "lamb's legs," which the pitman will fasten with a "German key;" the carpenter will fix his hands in the bench screw, until he cries enough; when the blacksmith should lead him by the nose, with red-hot tongs, off the ground so consecrated by practice; and the miller will derisively follow in his wake, as he pelts him with slimy pulp; thus he will be at the mercy of every practically efficient squeezer, until the professor has learned that one ounce of practice is worth a two thousand pounds' ton of theory, in such a place; and that, for such a purpose, theory but takes notes, whilst practice leads the way to success.

Would these same gentlemen put one of those practical men to superintend a college, or even to teach its lowest class? Certainly not. Then why put the collegian to superintend a mine and mining men? For one is just as consistent as the other.

For such abundantly palpable reasons as these, it very rarely happens, in the old mining countries, that a man under the age of forty years is selected to *manage a mine;* and even the *underground agents*, or *sub*-"*bosses*," who require but thorough knowledge of excavation, seldom obtain an appointment, who are under the age of thirty years.

It is, however, but too true that many, who have had the necessary practical knowledge, lacked sufficient education; but, if both cannot be obtained, choose the better of the two, as *practice can*, as it has done, *walk alone;* whilst *isolated theory* is practically a *cripple*.

Therefore, plenitude of arguments favor the practical basis, on which alone the superstructural theory can become valuable, for the more substantial purposes of mining.

Although it must be admitted that the American people are the boldest and best prospectors in the world, this deplorable fact must also be conceded, that their miners have too frequently undermined all rule, and consequent failures have been the general results for themselves, whilst ruination has befallen those credulous or reckless adventurers who were wont to become rich too promptly by this infatuating business. Worse than all this, legitimate miners, and the very business of mining in this country, have had to suffer from the mismanagement and rascality of such men; this interesting and most important branch of industry has been so retarded by these reverses, that many years must elapse before proper faith will be regenerated.

The more general history of the sage-bush mining schemes of the interior may be described in a few words, as follows.

A prospector, or his agent, induces some credulous resident of the city to believe that he has found, and obtained proper title to, a valuable ledge, in an immensely rich country (where all gains are greatly exaggerated, and the losses are never named). After some few interviews, the citizen or citizens agree to form a "ring," and to give the stipulated price; and then, being assisted by the elaborate reports of high professors (but low miners), they manage to form an *incorporated* company, so as to realize therefrom *almost* immediately.

With this prominent, yet silly idea, a mill is forthwith ordered, and the superintendent sent forward, to reduce the valuable ledge into bullion. It happens, too frequently, that no ledge can be seen; or, when found, it is worthless, for "all that glitters is not gold."

These incorporations are (by-the-bye) too often constituted by market miners, and are therefore as slow to see their mistake as they are fast in victimizing others; so that, after discovering that their funds have been thus recklessly squandered in the erection of a mill as an *enormously expensive assaying apparatus* (which but supplanted the experienced and honest mining engineer's examination), to show that the mine is worthless: they then devise means to rig the shares into the hands of others; and, until the inflated bubble has bursted, their victims are unconscious of danger.

It may happen that the vein is good; but it would then require many such rich veins to educate the men who have been generally sent to superintend the works, ere they would give profits from any mine, however valuable it might have been under proper practical management.

To carry on the numerous operations of a large mine, the Mining Engineer, or general superintendent, will require several sub-agents, to watch each separate operation, whose duties may be briefly named in the order of their importance.

1. The Underground Agent, or Captain—Has a very different duty to perform to that of the Mining Engineer; his education must be practical, but need not extend, in theory, beyond the mere rudiments of mechanisms and figures, unless he aspires to the future management of mines.

These men are generally, and *should always be selected*, from such of the experienced working miners who have had the most thorough practice in all the different underground departments, and who are already respected by their fellow-workmen for their practical ability, manly bearing, and general conduct.

Beyond these, their greatest recommendations are industrious habits, sobriety, integrity of purpose towards both employers and the employed, regularly consistent firmness of purpose, constitutional disposition to shoulder the wheel for progress, and good common sense; and, lastly (judging from many past examples), certainly not the least, free from that most damaging weakness, pride of office, which speedily makes them too good or pompous to do their duty in a proper manner.

There is never less than one Underground Agent, frequently two—the one by day, and the other by night; and, in larger mines, several, in proportion to the extent of ground, etc., laid open.

Their duties are, to closely watch all the underground operations, from day to day, so as to keep themselves posted about the value of the ever-varying veins, and the cost of excavating ground and extraction of minerals; to arrange all the necessary fixtures for the general workings; to keep

the levels clear of quartz by the hoisting machines, so as to make it convenient for all parties; to see that good ventilation shall be obtained, that the ground shall be securely timbered, or otherwise supported, when necessary, by the leaving of occasional natural blocks or arches of the rock itself, or by filling into such vacant sections the useless waste rock; to see that the ladders and ways are in good order, etc.; to supply, and keep account of, the necessary tools required by each party, and be present at each relief, to hear the wants and reasonable desires of the men; to see that the relieved men are properly cared for, as regards drying their wet clothes, and that the relieving men are all present, so as to descend to their respective duties; or, if absent by injury or sickness, to alleviate their pains, by sending the "club doctor and money" for their relief and comfort; to see that the blunt tools from the relieved men are forwarded to the smith's shop and re-sharpened; and make suitable arrangements with those who are working the hoisting engines, for drawing the "stuff" from the different shafts and levels; and to send down any extra timber, or other materials, that may be required for any particular purpose, during the succeeding "shift," or "core," etc., etc., etc.

Thus, it will be readily seen that this is a man of great responsibility, and should also be a most important officer in the working of mines, if he acted up to its requirements; but it *too frequently happens* that, although a man may be elevated from the miner, who has to *work eight hours each day*, for *half the Agent's pay*, he will, in a little while, become *so puffed up by silly vanity*, *pride*, *extra feed*, and *want of exercise*, that it will be considered an unnecessary bore to do his duty in a proper manner; and the deceived stockholders have to suffer for such an expensive ingrate, who is really an incubus on any adventure. He should be a steady-going, faithful man, who is both ready and willing to carefully examine the workings every day, and to attend to such other surface duties as are necessary for the proper working of his mine, in the cheapest and best practical manner.

Although these duties are difficult, they are not nearly as comprehensive as those of the Mining Engineer, or General Manager; and they are, moreover, so different, that, as a rule,

the best Underground Agent would make the worst Manager; whilst, for similar reasons, the best Mining Engineer would not excel when performing the more regular and isolated duties of an Underground Agent.

In very large mines, it is most advisable to have an agent or two for the *express purpose of watching the various stopes, levels, shafts, and winzes, for better knowledge of their comparative mineral values*, so as to be able to *let contracts under "tribute,"* at *so much* out of *each pound's or dollar's worth* of mineral that is extracted within stated limits of the vein's section.

2. THE WORKING, MECHANICAL ENGINEER.—The various duties of erecting the surface machinery, running economically, and keeping them in repair, devolves on this officer, as planned and supervised by the General Manager.

3. THE PITMAN, AND TIMBERMAN—Have to fix all the mechanisms that are required below the surface, for pumping, hoisting, tramming, ventilation, etc., etc. In fact, they are the subterranean engineers, on whom, in watery mines, the whole very responsible duties of drainage, etc., lie; and, consequently, if any serious accident should occur, the whole mine would be awaiting until their knowledge and practical exertions shall surmount the difficulty.

They are generally held in too low estimation, and insufficiently paid; are not even styled Captains; and, as soon as the greater part of the difficulty of fixing the pump work is over, they are required to work for less wages, or do other duties.

I have preferred to increase their wages, by promotion to Night Agents, when they can do both duties, in small mines; whilst, in large mines, they should keep their own particular division, and retain full pay.

4. THE INTELLIGENT LEADERS—Of the different "shifts" or corps of men, who act as responsible guarantees in the taking and performance of contracts.

5. THE ENGINE WORKERS—Who should be able-bodied and skillful men, for their duties demand it; but they are too often such as have been disabled for underground work; they

are therefore the most undervalued and worse paid in the mine. A good man earns thrice his wages, from greater safety and economy; whilst a poor man is dear at nothing.

6. THE CARPENTER—Is the general surface mechanic, wheresoever wood can be made subservient for any purpose whatever, in all the departments of mining; and very few there are who can be considered *first-class workmen and mechanics*, in that peculiar business of Mine Carpenter.

7. THE BLACKSMITH.—The good and experienced mining blacksmith should carry in his mind the essential forms and sizes of almost everything that is required for the iron mechanisms of mining fixtures, and should generally manage so as to anticipate such requirements. But this being also a business that requires much practice and experience, there are but very few who are really capable men in such a sense of the word; although, like the good *working* carpenter, he can manage to make anything that may be properly explained to him by suitable words or drawings.

8. THE CAPTAIN "DRESSER"—Is supposed to be well versed in the knowledge of the minerals as found in the particular mine, and with all of the best methods for preparing them, by hand picking and water treatment, for the market or the reduction works, and his studies are more particularly directed to rigid economy, etc., for beneficiation of ores that would not otherwise yield profits.

9. THE CAPTAIN OF THE CRUSHER OR "STAMPS"—Has the management of the crushing of the rock to the size of peas, as lead, copper, etc., and also of the stamps or battery, where it is crushed to a fine powder, and treated by water concentration, by appropriate division of cheap labor, etc.; or treated for gold on copper plates, etc.; or in pans, etc., for silver.

10. THE CAPTAIN OF CHLORINATION, OR OTHER CHEMICAL WORKS—Who receives the dry crushed powder from the battery, which he roasts, chlorinizes, etc., as most desirable.

11. THE CAPTAIN OF THE SMELTING WORKS—Who directs

the skilled workmen and laborers in all the fire operations of smelting, refining, cupellation, etc., etc.

12. A STORE-KEEPER—To keep charge of the store, deliver materials, and enter the amounts against the different men.

13. A CLERK—To arrange all books for practical operations, time-keeping, contracts, measurements, records, business papers, and to prepare abstract statements for all the financial purposes of paying and receiving.

Professor J. D. Whitney, in the Introduction to his work on "*The Metallic Wealth of the United States*," says as follows:

"The facility with which the public allows itself to be deceived, in regard to everything connected with mining, is as remarkable as the machinery by which the swindling speculation is organized and brought into successful operation is simple. The locality is selected, and visited by some very distinguished scientific geologist, who, for a sufficient consideration, will write a sufficiently flattering report, and demonstrate the absolute certainty of success. The value of the mine is fixed at an enormous sum, and divided into one or even two hundred thousand shares; the company is organized, and the stock brought into market. Every means possible is then taken to inflate its value; fictitious sales of ore are announced; the most flattering reports are received from the mine, and published in all the newspapers; the President of the company, who, perhaps, had never seen a mine before in his life, and who may therefore be excused for mistaking iron for copper pyrites, or perhaps even for gold, visits the scene of action, and finds the surface literally 'covered with stacks of ore;' a series of dividends is announced as about to be paid, or perhaps, even, the ore or metal from a neighboring mine is purchased with a part of the capital paid in, and sold, and a dividend declared 'from the proceeds of the mine;' the whole machinery of fictitious sales of stock is put in motion, the stock rises, and the promoters of the enterprise benevolently allow the public to step in and share with them in the magnificent profits which are certain to accrue. As soon as a sufficient quantity of the stock has been thus disposed of, and the getters-up of the scheme have pocketed the proceeds of their skillful maneuvering, the natural results follow: the stock, no longer artificially kept up, begins to droop; one after another, the deceptions which have been practised become suspected; the unfortunate holders rush to dispose of their shares, but it is too late. The property, which, a few days before, was quoted at hundreds of thousands, can now hardly be given away; the unfortunate victims have nothing left as the tangible evidence of the brilliant dividends promised but the elegantly engraved stock certificates, and the equally valuable reports by which they were deluded.

"And yet the mine, thus made the object of speculation, and perhaps abandoned in disgust, may be really of value, and capable of being worked so as to pay a moderate profit on the capital actually and judiciously invested in its development. But the idea was given out, in the beginning of the enterprise, that it could be made profitable at once, and because this has not been the case, the holders of the stock lose all confidence, and refuse to furnish the capital, without which hardly any mine, however rich it may be, can be put into a condition in which it can for any length of time be worked with profit. The system which prevails in this country, of chartered companies with a large number of shares, seems especially adapted to make the mining business, which contains so much of the lottery element of uncertainty in it, a mere object of stock speculations.

"The records of the last few years show, almost without exception, that com-

panies with large fictitious capital, and an enormous number of shares, have been got up for the purpose of swindling the public, and not for *bona fide* mining purposes. It may be laid down as a universal rule, that the stockholders in a mining enterprise should be kept fully informed in regard to the expenditures and operations of the company. A frank and full publication is the only guarantee of sincerity and good faith. When these things are more generally understood, and the public refuses any longer to be victimized, we may expect to see a less noisy, but far more effective, development of our mineral resources than we have yet had."

The English companies have also committed most serious errors, both in their selections and developments of mines in this country; for in the first place, they have sent men to examine, who, having passed their time in mining for base minerals, knew nothing of the formations that are most congenial for the precious metals, nor could they make *their own assays* of the vein, for estimation of its average value: secondly, *no company has yet emanated from either of the mining counties of England, to work mines on the Pacific coast;* but were, generally speaking, not miners in the true sense of expression; for, proceeding from the cities of London, Liverpool, etc., they were but "market miners:" thirdly, some of their superintendents were also strangers to the mining counties, and as notoriously deficient in practical experience of *all* mining, but more particularly that of *gold and silver*, in such remote and extensive regions.

So that even the mining of this splendid field of California has been defamed from a quarter, that, under other auspices, should have fostered this particularly interesting and valuable industry by more general successes.

CHAPTER II.

THE SYSTEMATIC AND MORE EXTENSIVE EXCAVATIONS MADE BY THE MINER, FOR THE BETTER EXAMINATION OF THE VEIN THAT IS SUPPOSED TO BE VALUABLE.

Being satisfied that the vein possesses sufficient visible value, or indicative merits (as ascertained by the method described in Chapter V, Section II), for further development by still greater expenditure, it becomes our next duty to consider the best means for its accomplishment.

When the sectional elevation of the vein, and the general surface contour of the ground, are both suitable, it is much better to drive a tunnel at the lowest possible convenient depth *on the course of the vein itself,* as it proves its quality, variations, angles, dips, spurs, and the more mineralized portions thereof; ventilates, by communication with suitably arranged shafts, the future workings; drains the water away from above, and lessens the height for elevation of what may be found below this level; as well as affording a more ready means for transferring the refuse rock, by direct route, into the future reduction works that may be erected below the exit level from this tunnel, the continuous rails from which may either run straight, or gently curved, to suit the requirements of their relative positions.

It will be generally found more convenient, for the working of *large mines,* to arrange the underground railway so that its car may be tipped into a *transverse line of larger cars,* which may be moved on underneath, as required for filling these several wagons of the surface railway, which should be drawn by horses, or propelled by steam engine, to the near or more distant mill.

It is often advisable to drive this tunnel a considerable

distance, before any shafts are sunk for ventilation, etc., for the purposes of discovering the positions, extents, and dips of the more profitably mineralized sections, so that these shafts may be correctly placed to command them; and it will be therefore necessary that some artificial mechanical means shall be used to ventilate the level, when the following modes are well adapted for this purpose.

1. "*Air sollars.*" 2. *Fire draught.* 3. *Water-fall blast.* 4. *Fan or screw blast.* 5. *Blast cylinders.* 6. *Inverted box, water-trough blast.*

1. "*Air sollars*" may be applied to great advantage for tunnels of five hundred feet long and upwards, as no driving power nor fuel is required, and there is no second, recurring cost.

The tunnel should be excavated of good serviceable capacity; if for a single track, which is always used for ordinary places, it may be from eight to nine feet high by from four to five feet wide in the bottom, narrowing to about two feet six inches at the top, which contraction carries the advantages of greater strength, more speedy conduction of the warmed air outwards, because of reduced volume, and much less rock to be broken where the room is not required, and which would cost much more to excavate when the dip of the ledge, which is often the case, conforms naturally to the slope of the one side.

First, construct an "Air sollar" in such a tunnel, when the rail wagon will also beneficiate operations, by laying down the rail sleepers about six inches above the bottom of the level; form an air-tight deck thereon, for the whole length of the tunnel, by closely planked mud joints, and then place thereon your rail irons for wagons.

This, by dividing the tunnel into two compartments, causes the under-current of air, kept cool by the water, to pass in to the men, as the rarified air passes outwards as an upper and continuous current.

2. *The Fire-draught Ventilator* also requires no mechanical power, and is, for many places, better and cheaper than any other method; it also has the advantage of extracting the

vitiated atmosphere from the very end of the drift, as soon as it is created. All that is required in this apparatus is to connect an air-tight pipe, that reaches from within a few feet of the end of the drift, through the upper part of the level, to the enclosed ash-pit of a furnace, that is built above the entrance of the tunnel; and if this pipe is kept quite tight throughout its whole length, four inches in diameter will be quite sufficient for all ordinary requirements.

3. *The Water-fall Blast* is available where a stream of falling water can be passed in various ways down a pipe, to impinge on, and scatter from, a flat surface into a trough; the air that is forced to accompany it in its precipitous descent, from suitable side inlets, is conveyed from this trough, or box, by pipes, in to the workmen.

4. *The Fan or Screw Blasts* are very effective; more especially so when fixed to extract the foul air directly from within the end of the level, to discharge it into the outer atmosphere, which the screw does in a direct manner, and the fan by attaching the extracting pipe or pipes to one or both sides of the centre openings of the fan box.

5, 6. *Cylinders*, and *Water-trough Blasts*, can only be conveniently used in shafts where a reciprocating power, for other work, is present and available for this purpose.

In the meantime, numerous pits should be sunk on the croppings, and closer examinations made for all spurs, cross-lodes, or channels of ground that in any way may enhance the value of the property, or throw more light for facilitating the development, or enhancing its probable value.

When a portion of the vein has been discovered by the surface operations, or driven through by the tunnel, that fully demands deeper exploration, a shaft had better be commenced in the best possible position for commanding the more mineralized sections of the lode; and, in the earlier stages of mining, it is very often much better to sink it in or over the vein, than perpendicularly through the bed-rock; as the most important object, of proving the value of the lode, is thereby continually obtained, and generally at more moderate expenditure.

This, however, depends on so many considerations, that a general rule will not apply.

The old-fashioned method of hoisting, when "kibbles" or buckets were drawn from the bottom to the top of the mine, by being slidden over the rough foot-wall, or, at best, on wood planks, which frequently made considerable wreck and delay from wear and tear, greatly favored vertical shafts. This relic of barbarism must now pass away, and be supplanted by the more regular action of diagonal railways, both for the elevation of the minerals and conveyance of the heavy pumping appliances, etc. So that, with these greater facilities for collecting and hoisting the minerals, etc., and in view of all the other phases of development, such as exploration, errors of position, dips of ore, changes of underlie, with the chances of unnaturally hard ground in solid country rock, deferred returns, etc., there are few mines that would have been much benefited, in their early stages, by vertical shafts, and their attendant cross-cuts.

There are, however, some positions where soft stratum prevails, as well as others, in later developments of large mines, where an extra shaft is imperatively necessary in a certain position, to command fully established and extensively mineralized ground, and drain the water. In such a case, a well-placed vertical shaft would enable the miner to increase profits and obtain much greater depth. This is, however, in such circumstances, a plain matter, when figures will readily test method against method, and not governed by the uncertain contingencies of young and virgin mines.

Therefore, if you prefer keeping company with the vein, you can sink the shaft thereon to communication, when splendid ventilation will be secured to both, and the tunnel may be continued forward, as the shaft is being sunk under this level, by cutting ground under the foot-wall for the loaded wagon to pass, without endangering the shaft-men, which will also serve as an occasional discharge-plot for both.

If the stratum above the lode is soft, and otherwise favorable, and you anticipate requiring pumping power, it will be better to sink a perpendicular shaft, to intersect the vein some few feet under the level of the tunnel, so as to have a

short cross-cut thereto, some six feet above the bottom of this tunnel, for the advantages of tipping the rock from the shaft-wagon into that of the tunnel, and sufficient side space for the more uninterrupted working of the shaft and tunnel simultaneously.

To adopt this method, you should be well satisfied that the shaft is in a good position for dip of mineral, main drainage, and hoisting; and make it of proper size—say twelve feet long by six feet wide—securing it with timber, if necessary, as you go, suitable for such purposes; and after reaching the lode, to sink thereon, extending the shaft two feet longer at the pumping end (fourteen feet in all), and five feet wide, as the upper part of a diagonal shaft is useless, because the work lies mostly on the foot-wall.

If the water is light, the shaft may be thus deepened by a good horse-whim, to from three to four hundred feet, and levels driven away on the lode, at some six feet above the bottom at this depth.

The double-handled windlass, or common "tackle," and the horse-whim, are the only hoisting appliances that are really necessary in this stage of mining operations.

The "tackle" is always made and erected for work in exactly the same manner, in Cornwall; as follows.

Two pieces of timber are selected, which are sufficiently long and strong to reach across the shaft, and bear the strain of the work; in the middle of each piece, a hole is cut (lengthwise), about eight inches long and one and a quarter wide, to receive the bearing columns of plank, which are about five feet long, twelve inches wide, and one and a quarter thick; these uprights are shouldered down on, and mortised into, the long holes of the bed-pieces, and grooves or slots are cut downwards from the top for about twelve inches, sufficiently large that the axles, which are generally made of one and a quarter inch iron, may drop to the bottom; the bottom of this slot is now lined with iron, as a wearing piece, which should also be of suitable shape, that, when strongly screwed or nailed on, it may prevent the thin plank from splitting under the weight of the work.

The supports, being thus made, are ready for the windlass, which is formed from a piece of strong Norway pine; it is

from three to six feet long, and from eight to ten inches in diameter, according to the requirements of the case, as governed by the fancy or strength of the workmen; the ends are then drilled to receive the wedge-ended handles; and, lastly, bound by wrought-iron hoops, so as to insure the proper security for the handles.

Two pieces of one and a quarter inch round iron are next taken, about three feet eight inches long; the one end of each is either made of a **T** or **L** shape, or is sharpened to a wedge, or squared to a taper, or a hole stamped through the end; they are then bent twice; at a right-angle to the angle of a square, so that the first or tapered end of each may be about twelve inches; the middle, or cranks, fourteen inches; and the handles eighteen inches long. These single pieces of iron are thus made, and when securely driven into the barrel ends, at opposite halves of the circle, they serve for attachment, axle-crank, and handle.

The bearers are now thrown across the shaft, at the proper distance apart, and, after a flooring of boards is first nailed from the one to the other, the handled barrel is dropped down between the standards, with its axles in the vertical slots; a head-board is then nailed across the top, and diagonal stays against the sides, when it is ready for use.

The superior tackles have also an iron or wood bar, that reaches across the top, guided and secured by strong staples, so as to stop the machine at any point of elevation, by sliding the bar out across the path of the cranks. Also, a friction leather, for lowering with greater ease and facility. Such a windlass can be used for hoisting from the maximum depth of one hundred and twenty feet.

This shaft "tackle" is generally made entirely of wood, in America; the barrel is shaped to small necks, at about four inches back from the ends, which, when greased, serve as axles; whilst the extreme ends are squared for wooden cranks, which have also wooden handles driven into suitable holes at the outer ends of the cranks.

The "horse-whim" is generally made as shown by Cut 34, which explains itself; but it is at a greater distance from the shaft-tackle, as it is shortened to suit the width of page.

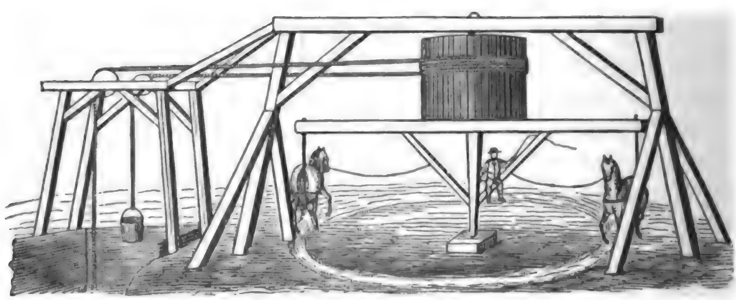
The centre part, which carries the ropes, is sometimes

made differently, and the machine is then called the "forked whim." The ropes work in separate recesses, which are about nine inches wide, formed by wood arms in iron centre-pieces, and as the buckets or "kibbles" ascend the shaft, these barrels become larger, and less power is then in operation, with greater speed, when not required for hoisting the longer and heavier chains that are used for these whims.

Such machines, when the work is not too much, will hoist from a depth of from three to four hundred feet, and are most efficient at from one to two hundred feet. The rock is hoisted in buckets, and the water in barrels, with leather-faced valves at the bottom, for admitting and releasing the water.

The "horse-whim" is most frequently worked by a single horse, or a pair, at one end of the lever, as directed by a boy; but may be worked in the manner shown, or by two pairs of horses.

Cut 34.



If the quality of the quartz has been fairly noted, you have prospected the ledge sufficiently, and the time has arrived for one of three things.

1. To ascertain if the rock will more than pay, at and above this level, in quantity and quality for mining and milling. If it will, obtain a mill, or suitable reduction works.

2. If it is not sufficiently rich at this depth, does it give reasonable guarantees that it will become so at greater depth? If it does, obtain a company who will run the risks of the necessary expenditure required for machinery to develop it.

3. If it does not, abandon this worthless property.

Consistent discretion is more valuable than reckless valor, in mining as well as in war; for a too sanguine miner ruins fifty companies for one that he benefits.

CHAPTER III.

MECHANICAL ENGINEERING, ABOVE AND BELOW THE SURFACE.

Next to that of finding a good mine, there is nothing more difficult, in the whole field of mining, than the arrangement of the mechanical appliances in the best manner for the development and most profitable realization of whatever the veins may contain; and yet this part has been very often disregarded in planting the surface mechanisms, more particularly in the initial stages of operations, as the almost general rule has been to entirely destroy the early erections, to make room for the several superseding powers which follow, from the hand "windlass" to the single or double-horse "whipsedary," to the "horse-whim," to the "steam-whim," and the "steam capstan." So, also, it as frequently happens that the smaller engines and pumps are followed by larger ones, for pumping, etc.; so that by the time the wrecks from alterations and substitutions are cleared away, and the consequent delays are paid for, little will be left for making profits, even from mines that would have been, with fair play, profitable.

Mills and stamps also are very often obtained too soon, before it is known if they will be really wanted; therefore, they are either not required, or are insufficient for the quantity of mineral to be treated; so that, *firstly*, the outlay could have been entirely saved; and, *lastly*, the double erection, with its consequent destructive waste, would have been likewise prevented, and so much larger profits given.

Therefore, all these things should be well considered about this time, and a provisional intention for the future should pervade the whole system of mechanisms and mining, instead of the most stolid disregard that is often shown towards all agreement with the subsequent erections and excavations that are naturally to follow.

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For these reasons, I have divided "Mining" into two chapters, the one for mere examination by the inexpensive preliminary appliances, for hand and horse-power; and the other for mining in proper manner, by the most suitable and powerful water or steam machinery, to the greatest possible depths.

The trifling machinery required for shallow preliminary mining has been described in the last chapter, where required; and those more ponderous engines for deep and extensive mining will be separately explained in the next chapter, which precedes the one on "Deep Mining, as Facilitated by such Machines."

MECHANICAL ENGINEERING BELOW THE SURFACE.—Beyond the necessity of his aid in the elevation of the water and the minerals from underground, the mechanical engineer has not been encouraged to perfect this department; and the hard-wrought miner has therefore to perform many unnecessary and toilsome operations, that are really too burthensome for him, who is already oppressed with the hardest and most disagreeable labors that mortal man is heir to.

There are many things that could be done much better by small and conveniently arranged machines placed beneath the surface, which would not only ease off the most laborious parts of the miner's duty, but so facilitate the work that much more could be done in the same time, and many very desirable things performed, that, under the present merely muscular and contemptible slaving system, cannot be accomplished by ordinary means. The most desirable and prominent of which are the hoisting of rock during the sinking of engine shafts under the "pentices," below the fixed plats from whence the surface engine hoists the minerals; and the hoisting of water and rock during the sinking of winzes, to the depth as now sunk, as well as much deeper when required, which is often very desirable for working or proving the dip and extent of deposits of mineral, in remote wings far removed from shafts, *where it would be ruinous both in money and time, to extend the levels at every one hundred feet, as under the present muscular system; or to sink a new shaft all the way from the surface, but to prove the ground.*

The necessary power for this work may be either generated by the main pumping rod underground, or the surface engine may force air into a boiler as a reservoir, to be conveyed to the required places through comparatively small pipes, for working the small engines; this compressed air, having performed the work, would then aid in the better ventilation of these sections, as it escaped into the level.

Or the power may be water, which could be obtained at more than sufficient pressure, from the column of water over the engine-shaft pumps at the different levels, and conveyed by still shorter pipes through the level to the machine, and, having done its work, it would return, by running through the level into the cistern, and be pumped away to the surface.

The small quantity that would be thus required, *under such a pressure*—say but from two to ten men's power—would not disarrange the working of the pumps to any practically inconvenient extent.

Compressed air may be also used in some rare instances, for rock-drilling machines, where large double-track tunnels have to be driven in homogeneous and compact ground; or in open cuts, where there is plenty of room. The mechanical driller will not, however, be generally used for the ordinary sinking or driving of small shafts and levels, unless very much improved from those now in use, so as to combine efficiency with compactness and trifling weight.

The machines are now so unwieldly, that the trouble of *fixing for drilling*, and *removing them from* this ever-varying work, previous to blasting, and the consequent necessity for keeping the level of the shaft entirely clear from the broken rock, will far more than outweigh their advantages, even were they given to the miner free of cost.

In new countries however, where labor and materials are very high, they may become somewhat advantageous, under peculiar circumstances and requirements.

CHAPTER IV.

THE HYDRAULIC ENGINE; THE CORNISH PUMPING ENGINE AND PUMPS; THE HAND AND STEAM CAPSTAN, HOISTING MACHINES, MAN ELEVATORS, AND TRAM ROADS.

The most ancient working powers were derived from falling water; and being still the most efficient, trustworthy, and economical, it should be always used when present, and even when near, it must never be despised, when it can be rendered subservient to, and more economical for, our purposes; but when it can only be obtained from a great distance, by large outlay, the following questions should be first satisfactorily answered.

What is the *least time* that either this, or steam power, *will be required for the performance of the necessary work?*

How much will it cost to buy, erect, and *maintain*, steam power for this period?

What will the water flume and machine cost?

If they should be equal, which of the two is preferable from *other* stand-points?

And thus your determination may be ratified. If the mine should work longer than the minimum estimate, the water will be henceforward a costless power, and consequently a continual profit, as long as you may require its reliable services.

It needs less expensive attendance, and is free from all danger from explosion, etc.

In the explanation of the hydraulic engine, I may say that I was consulted, some years since, by the Directors of the Great Onslow Consols Mine, in reference to the erection of suitable machinery for the more extensive development of their property, which is situated at about the middle of the County of Cornwall, England.

On visiting the mine, I found that their water-wheel, of

forty-six feet in diameter and five feet breast, which was being used for pumping the water out of the mine, then about four hundred feet deep, was insufficient for greater depth, and had been a great hindrance to their progress during several of the immediately preceding summer months.

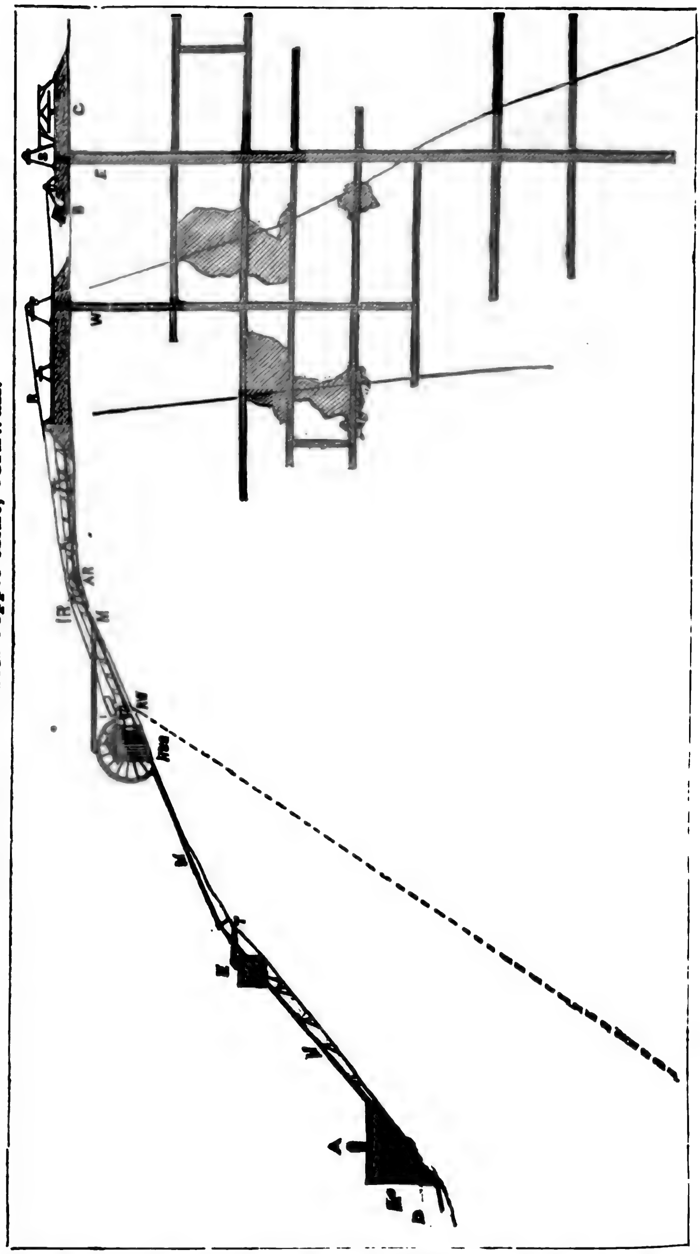
They had therefore become disgusted with this water-wheel, and had already purchased a steam engine for hoisting purposes, and wished to know, previous to buying a steam pumping engine, what size or power would be most suitable and economical for this work, etc., etc. Happening to enter the property from the right direction, I saw at a glance that the same water might have a very much greater fall, by a diversion of its route, and which was proven, the next day, by actual levelling, to be some two hundred and eighty feet. I arranged that the steam engine should be sold, and the water used for all purposes. This pumping wheel was then transferred to another more suitable site, and erected in proper position at the head of this fall, for hoisting (on its one side) the rock from the mine, and for crushing the ore (on the other side); a double-track rail was also laid down, so that the full car, as it descended to the mill, might hoist the empty car to the mine.

THE HYDRAULIC PUMPING ENGINE—Was erected at the foot of the hill, at the bottom of the remaining fall of water, and supplied through a cistern head E, into the pipes that were placed above it, to do the amount of work that was then required; and as the load increased, the pressure column was also increased in height *occasionally*, so as to provide a commanding excess of power.

The general profile of the hill, with the relative position of the mechanical appliances for pumping the water, as well as for hoisting and crushing the mineral, are all shown by the accompanying illustration (Cut 35).

Many attempts had been previously made to pump water, by the power of water under great pressure, in a direct man, ner, like the Cornish steam pumping engine; but, for want of proper adaptation of the parts to suit the *more weighty-non-elastic* water, thorough success had not been obtained until this instance. Of course, the French tourbine, and the

Cut 35.



Section of the Underground Workings, Surface Contour, and Hydraulic Machinery of the Great Onslow Consols Copper Mine, Cornwall.

D—Discharge. H P—Hydraulic Pumping Engine. A—Air Chamber. M M M—Main Pumping Rod. E—Entrance of Water. T—Turnpost. H & C—Hoisting and Crushing Machine. R W—Railway Wagon. I R—Incline Railway. A R—Angle Reel. R—Rope from Whim to Shaft. W—Whim Shaft. B—Balance Box. E—Engine Shaft. S—Shears. C—Capstan.

many modifications thereof, with *rapid circular motions*, and *extreme distance* of the machine power from the shaft, would have been *perfectly unavailable* for this, and most other, *pumping purposes.*

The working cylinder of this engine was twenty-five inches diameter, and the piston rod was connected in a direct straight line with the main pumping rod, which passed over the irregular hill's surface on flat rollers from the machine to the engine shaft, having balance-boxes and stop-catches where necessary.

The pressure column, which also conformed to the hill's shape, was of but eight inches internal diameter, and at the lowest possible point, just over the entrance valve to the engine, was placed an inverted vertical air column, which was twelve inches internal diameter and about nine feet long. The water, in its passage to the machine, brought down sufficient air in its interstices to supply this chamber, and it thus formed a magnificent cushion against the enormous pressure that was created by the momentum of the long, quick traveling column of water, that was so suddenly occasioned by the valve in its action for stopping the stroke of the piston, main rod, pumps, etc.

To govern and graduate the admission and release of the water, so as to place the engine under perfect control, a separate engine was used to work the main valve; which engine could either be worked *by hand in starting*, or by the *main rod*, in an *ever-continuous*, *self-acting manner.*

The whole of the valves, too, were of peculiar construction, and balanced for better floatation, so as to lessen friction, wear, etc.

After these machines had worked for several years, an experienced examiner of mines (the late Captain Nicholas Vivian) said that they gave the mine an advantage over all others of the County of Cornwall, from efficient and economical water-power mechanisms.

Thus, the rejected power, when differently applied, became the most subservient auxiliary for successful mining.

It may be arranged for hoisting, crushing, milling, blowing air, etc., with even greater facility than for pumping; and where equally regulated powers and speeds are required, nothing can sur-

pass its performance, for when the governing valve is throttled under excess of height and pressure, it has a clock-like equality of motion, which is but slightly affected by the variable amounts of work performed.

THE CORNISH PUMPING ENGINE AND PUMPS ARE IMPERATIVE NECESSITIES FOR DEEP MINING.—The Pacific slope is destined to become an extensive mining field; each year will deepen the developments of mineral veins, and the difficulties of pumping water and hoisting stuff therefrom will geometrically increase as depth is attained; so that many mines will waste their proceeds, and succumb for want of mechanical appliances for deep mining. It is therefore imperatively necessary that you should profit by the experience of others, and discard those non-expansive rotary engines, that are entirely unsuited for pumping water from deep mines, from imperfection of structure and extravagance of fuel; or continuously recurring difficulties and accidents will have to be encountered, and these temporary machines discarded for the more appropriate, substantial, and permanent pumping engine, at a time when, from excessive water and concomitant expense incurred by delay of operations under full staff, the cure of the evil will cost far more than the prevention.

It is not uncommon, in mines from 1500 to 2500 feet deep, that pumps of from fifteen to twenty inches in diameter, varying from eight to ten feet stroke, are required, where the quantity of water is so very excessive that a hindrance of twenty-four hours would be extremely ruinous to the financial balance; so that nothing but the most efficient arrangements can secure continued and successful labor, with economy. The experience of Cornwall in this department is more valuable than that of all the outside world. I will therefore endeavor to describe the "Cornish Pumping Engine," which I deem vastly superior to all others for pumping, and hope it may be adopted here as elsewhere, before it is too late; as it is equally well suited for all stages of mining, intervening between the discontinuance of the "horse-whim" barrel, and the deepest developments of man; saving, as it does in every way, from its admirable adaptation to the work, not only in fuel, and in wear and tear, but also

by less breakages, hindrances, and consequent loss of mines. This engine, contrived especially for pumping water from deep mines, by several of the best engineers in the world, is exceedingly well adapted for the purpose; in fact, it is for the miner what the direct-acting steam hammer is for the blacksmith, and performs with ease and precision duties that could not be otherwise accomplished; and therefore embodies many peculiarities, some of which may be described as follows.

We will suppose that a ponderous scale-beam is poised on what is termed the "bob" wall of the engine house; the *inner scale-pan*, being suspended by the piston rod, constitutes the piston of the cylinder, and the *outer scale* being the representative of the various pumps vertically suspended to the outer end of the beam by the main (directly connected) rod, that extends from the surface to within some fathoms of the bottom of the shaft. It has no crank or fly-wheel, nor is it confined to an exact, undeviating length of stroke; but it can be moved at the pleasure of the worker, for all desirable lengths, and is in itself continually varying within certain limits, as the load in the shaft, or steam's pressure in the boiler, may increase or decrease, etc.

Engines of this description have varying sizes, from twenty to one hundred and forty-four inches in diameter of cylinder, of from nine to twelve feet stroke of piston, and from eight to ten feet in the pumps; the comparative length of inner and outer ends of the main lever being governed thereby, after the relative ratio of one foot eight inches for each foot of the stroke; a ten feet stroke of piston having sixteen feet eight inches for inner length of beam, the outer length being for a nine feet stroke, fifteen feet beam; which are the lengths preferred, for large and small engines alike; because of the better actions of expansion and practical pumping by the quicker travel of the steam or piston end.

The number of strokes per minute is regulated by the screw governor, of an automatically contrived hydraulic timekeeper, either for an intermittent motion of one stroke in ten minutes, or any required number up to twelve strokes in one minute; being sufficient for the greatest variations that are required in mining, and extremely exact for regular extrac-

tion of water. The time of making individual strokes is also varied, and made subservient for the requirements of both the engineer and shaft-men, by elevating the load by *more or less expansion*, in from two to six seconds, and returning the pump-rod with attachments for ensuing strokes, by balance in from four to ten seconds; the latter being sometimes further restricted in dangerously quick descent from pump-valves chipping, by the partial opening of the equilibrium or outlet valve, as its handle is bridled by a rope.

As the weight of the pump-rod, with fixings, is more than the weight of the water to be lifted, or the work to be performed, the action has been reversed; and the power of this single-acting steam engine is employed only in lifting their weight, which, in descending, performs the work on the consecutive plungers or force-pumps, placed at distances of from one hundred and fifty to three hundred feet asunder, and which extend from the surface to the bottom or suction pump, that is invariably used in sinking shafts, but promptly substituted by plunger fixtures, as soon as possible, to relieve the extra strain from the main rod, to lessen the weight in the balance-box, and consequently friction.

These force pumps are sized for the quantity of water to be pumped from their respective levels; which is a matter of careful consideration, to prevent wasteful differences that would have to be re-lifted in their successive supplies, to keep the larger pumps full of water.

The suction or "draught" pump is always made larger than those above, to give the shaft-men the advantages of its ventilation, greater certainty, durability of leathers, and more speedy clearance of the water from the very bottom, previous to drilling or charging sinking holes.

The pumps should never be worked faster than is necessary for their full supply; which is so exactly and beautifully performed by this engine, that a whole watch may be frequently passed without alteration of speed, or excess in the number of strokes.

The engine has four balanced, double-seated valves, called the "governor," "steam" or "expansion," "exhaust," and "equilibrium;" the first is varied by a screw motion; the second, third, and fourth by handles, and self-acting, leather-

faced slides or "plugs" attached to and worked by one or two parallel and perpendicular rods from the main beam, which plugs are adjusted to the varying requirements of the work to be performed.

Modern engines are all fitted with air pumps and condensers; but they may be worked as puffing engines, for peculiar places.*

The boilers also known by the name of Cornish boilers are composed of two cylinders, secured by one end-plate at each end, the fire being lighted in the inner cylinder; the flues range through the inner tube, back by both sides, and pass by one channel underneath the boiler, away to the chimney, at a less temperature than 212°; the gases from combustion being deprived of all efficacious heat. They are each provided with stop and safety valves, glass gauges, and gauge cocks, separate dampers, feeds, etc., so that one or more may be worked; thereby enabling the workmen to repair, or cleanse, as often as may be required, without delaying the workings of a deep mine.

The pressure of steam is from thirty to sixty pounds per inch, but generally about forty pounds, and is admitted and released to and from the engine as follows. The engine-worker, standing before the handles, slips the catch of the exhaustion handle; this valve opens communication to the condenser, and at the same time the motion admits the injection water from the cistern to the condenser, which being allowed about two seconds for entrance and condensation, the catch of the steam is lifted, and the steam handle and valve opens and admits steam, properly regulated by the governor valve's screw, by slow additions; the descending motion of

* The largest and heaviest engine that was ever made, was manufactured some twenty-six years since, by Messrs. Harvey & Co., at Hayle Foundry, Cornwall; for the drainage of the Harlaam Lake, Holland: its outer cylinder was one hundred and forty-four inches, and the inner cylinder was eighty-four inches in diameter. It worked thirteen levers, which intruded their inner ends and rollers under its large and ponderous piston rod's "disk cap," whilst their centres were supported on the embrasured wall of an immense round-house, and the outer protruding ends worked as many sixty-inch pumps of from ten to eleven feet stroke, some ten strokes per minute. This engine was modified to suit the requirements of this case, where a very large quantity of water had to be lifted but a short distance.

piston rod or beam being closely watched, so that, if necessary, the steam valve may be closed, the exhaustion from beneath suddenly stopped, and the engine's motion arrested by the cushion of retained vapor; the equilibrium handle and valve is next opened, to allow the steam to escape from the top of the piston to the bottom thereof (in equilibrium), just as fast as is necessary for the ascent of the piston and the descent of the pumps, by the balance, which must be now adjusted by throwing the balance rock into or out of the box. The cylinder-full of steam is retained, until the exhaustion valve opens to repeat the next stroke, to support warmth, and prevent inhalation of atmosphere, that would vitiate the perfect vacuum; separate steam is also turned into the piston rod stuffing-box, for similar purposes, and the whole of the surfaces of boilers, steam boxes, pipes, and engines are thickly covered with a non-conducting substance. A few strokes is all that is necessary, with skilled drivers, to render the engine self-acting and properly balanced; the correct speed only remains to be ascertained and regulated. Suitable preventive catches or stops are made, of great strength, at each end of the stroke, so as to prevent accidents from loss of lode, etc., etc.; and a code of numerical bell signals are used, to inform the drivers of the requirements of the shaft-men; thus, any number above ten means to work or stop the engine; seven, work faster; six, slower; five, take her up slowly; four, lower slowly; one, stop, or hold fast, etc., etc. These are performed, by the peculiar adaptability of the engine for the work, as well as all other requisite movements, with great facility, exactness, and dispatch (that can be approached in precision by no mechanical movement but that of the steam hammer); and the engine shows, moreover, to an experienced eye, on the face of her every movement, the faults of the pit-work, and where the error is located. The above numbers are arranged so that they shall not conflict with those for the hoisting machine, where three means to hoist, and two to lower.

These eminent advantages, from the general adaptation of direct action, intermittent motion, slow combustion and generation, minimum friction and radiation, with maximum expansion of steam, cannot be despised with impunity; as

they reduce the consumption of fuel from fifty to two hundred per cent., as compared with many rotary engines now placed on this work, and enable the miner to attain thrice the depth, with greater comfort, and much less anxiety and danger. I would therefore, in conclusion, most emphatically impress the importance of the Cornish arrangements for pumping, both above and below, in the steam engine and pump fixtures, as possessing superlative advantages, for efficiency and economy, that can be fully appreciated only by the most experienced practical men; but which are, notwithstanding, so well recognized in the English mining market, that no prudent man will buy shares in a mine having an "extravagant rattle-trap rotary toy" for pumping, but will prefer waiting for the regular pumping engine that must inevitably follow, to properly develop a mine, even where fuel, labor, and materials are cheap.

If such arrangements are discarded there, how much more strongly should they be condemned in this expensive country, where greater profits are expected to be realized from mining? To be forearmed has been considered half the battle; so let those interested take warning, and be prepared for these contingencies, before it is too late.

It has been stated that this engine is much more heavy and costly than the common engine; but, as it has no fly wheel shaft, fly wheel, nor tooth wheels of any kind, this is as evidently as it is substantially untrue.

In fact, one peculiar kind, called the "bull engine," by being applied in a direct manner to the main pumping rod, has not even a main lever, nor other weighty parts, save the cylinder, piston and rod, with the valves and small gear.

When necessary, the large and more complete engine may be much lightened by having the lever made of malleable "boiler-plate" iron, or even of wood, on the mine, which may be bridled with iron from each end over a central "king-post" of wood.

By either of the last arrangements, they are preëminently light engines. With metallic pistons, the cylinders may be even made in several accurately jointed, flanged rings, for carriage into mountainous regions.

The best and lightest tubular boilers may be also substituted for those previously explained.

I would not that local founders should suppose that I am advocating the necessity for its direct importation from the Cornish engine-makers (although it is a rather strange fact that, although some of the largest and best of the outside city founders have tried their hands at it, both for waterworks and the coal mines in the north of England, yet still those made and erected by the Cornish have always surpassed all others, both in efficiency and economy); my intentions are to benefit the mining of this country, and therefore you.

They must, however, be made and erected in a proper manner; and there are those here who can now, as oftentimes before, either draw, make, erect, or work them afterwards, if it should be necessary to do so, in precisely the same manner as they are made, erected, and worked in Cornwall.

THE HAND CAPSTAN—Is generally placed on the opposite side of the shaft from the horse-whim, and may be described as follows. A skeleton frame is first erected, similar to that for the whim, but is somewhat lower, and much stronger made, and stayed by a straight "studdle" or "shore," from the head beam to the shear leg, so as to be perfectly safe against all the weights that it will ever be necessary to lift or lower therewith. A strong wood axle is next made, which is square in the middle and round at the ends, and into each end an iron axle is secured, when the ends of the wooden axle are strongly bound by shrinking on wrought-iron hoops. The *bottom end* of the wood axle, which must be from eighteen to twenty-four inches in diameter, has a thin disk of wood, of about thrice this diameter, which is brought up over the iron axle, square under the end of this wood, so as to form a true support and platform, to guide the winding of the rope on the reel, and to prevent it from dropping.

The bottom iron axle is now placed straight down into the hole that has been expressly drilled into a heavy stone, and the axle, being thus erected, is also entered into the upper hole of a piece of strong iron, that has been screwed on to the beam. From four to sixteen arms are now fastened on to the square part of the axle, in the manner of fixing for

a water-wheel, at about the height of a man's elbow, and the central half of the whole is covered with a central and conical wood roof, to protect the rope from rain, etc., when the rope can be now put on, and a gangway cut from it, in a straight line from the working side of the axle to the shaft-pulley, so that it may pass entirely under the roadway.

Small suspension rods may be now fixed from the middle of the main arms to the upper end of the axle, to support their weight, and it is ready for being manned for use. The capstan rope is first passed out through the subterranean gangway, over suitable rollers, and under a pulley in the leg of the "shears," thence over another at its head; both of which having been previously placed in proper position for commanding a suitable direction of the rope from the capstan axle to the lower sheave, and its *central drop* from the upper pulley into the *shaft* or *capstan-way*. (See Figure C, Cut 35, in the sectional surface contour of the Great Onslow Consolidated Copper Mine, and its machinery, page 374.)

THE STEAM CAPSTAN—Is almost a necessity for deep and extensive mines, as the hand capstan is not only too slow in action, but also too expensive, as it requires so many men to work it, when heavy weights have to be lowered or elevated great distances.

It has been the practice to employ an especial engine for this purpose; but the arrangement shown by Cut 36, for the surface mechanisms, simplifies and cheapens the initial stages of mining, so that one thing shall follow another, without destroying the old arrangement of parts to make room for the new; and, in this connection, the double cylinder, expansive action hoisting engine performs both duties, by merely disconnecting, by an easy arrangement of motion, the hoisting or capstan gear, as required. The other peculiarities will be described in the chapter on "Deep Mining, as Facilitated by such Machines." The steam capstan is shown, in the act of hoisting a piece of main rod, with the side "strapping" or connecting plates attached, for greater facility in connection, when lowered to its place under the other rods.

You will notice that peculiarity of the shears, where the shieve is so fixed that the rope works outside, instead

of underneath in the usual manner, by which the rod may be *hoisted to the very lashing*, so that a much less height of shears will suffice.

In this arrangement, the pumping engine and the hoisting engine are at right-angles with the vein; the former is on the foot-wall side, and the balance beam is towards the vein, and intentionally placed in the direction where, in the future working, a pumping rod may be required.

In this instance, which I have given as an example, two horizontal engines are fixed to work on right-angled cranks, one at each end of the hoisting drum or reel, the whole being fixed on strong wood bearers, that run the whole length, and which are screwed down on a heavy stone loading, and thus this part is complete; but, in order to render it suitable for capstaning also, a tooth-wheel of about thirty inches in diameter and eight inches wide is keyed on to the shaft (which is made thus much longer for this purpose), just inside of the stool.

Into this wheel another tooth-wheel of about six feet in diameter must be geared, in such a way that it may be slidden in or out of gear by a suitable screw; in this shifting, the wheel and this end of the shaft is moved, but the other end need not be movable; for either a ball-shaped journal may be used, or the stool may be swivelled thus much, so as to turn on a centre. Thus, both the hoisting and capstan barrels are opposite their respective works or parts of the shaft. In this instance, the former has a wire rope, which serves for double hoisting, by working on a plain cylindrical barrel of not less than nine feet in diameter (the shaft-pulley being twelve feet), whilst the latter has a flanged drum of about four feet in diameter, on which is secured the end of a hemp rope, the size of which is somewhat governed by the diameter of the pumps; it should, however, never be less than about eight inches in circumference, and, when the diameter of the pumps exceed this, the rope's circumference should follow equally, as a nine-inch diameter pump should have a nine-inch circumference rope; an eighteen-inch, an eighteen-inch rope, etc., and as long as is necessary for the working of deep mines; it will, however, be better to first have the rope about one thousand feet long, as, by the time this depth is attained, a new one will be necessary.

THE CORNISH STEAM CAPSTAN—Has been generally, if not always, worked by one long-stroke vertical engine, which is mostly kept for this express purpose; but it may have been also used for the elevation of the men from very deep mines. This engine is fixed half in the house and half without, so that the beam may work on the end wall, like the pumping engine (shown at Cut 36); but with this difference, that the connecting rod is attached to, and follows, the circular motion of a crank.

The crank-axle has, of course, the pinion wheel, which is geared into, and drives, the drum axle wheel, of about four times its diameter, which is suitably fixed in position to command the shaft. Two-legged shears are almost invariably used in Cornwall (like that shown in Cut 35, over the engine shaft), and they take a position that is about parallel with the front of the engine-house, or in a lengthwise line with the engine shaft, when the engine is fixed as shown by Cut 36; but the shears has to be frequently turned in a somewhat oblique direction, to avoid the balance beam, which is also generally fixed at the end of the shaft, unless there is a much stronger probability or direct intention that *parallel lodes* will require the water to be pumped therefrom, than the extreme end of *this lode*, when the balance beam is placed in line to do so.

This very lofty biped shears has a large and small pulley fixed over its head, in such a way that the rope can only work through the cap's bearers; and therefore much height is wasted, as long rods cannot be hoisted nearer than some twenty or thirty feet to the fastening rope or chain, without swaying the bottom end of the rod far away from the shaft, as it approaches under the cap.

The end of the capstan rope being first secured to the barrel, the whole of the rope is carefully wound thereon, and then unwound and passed back, over rollers, through the nearer foot of the shears (in which there is a suitable pulley, fixed in line both with the "capstan" barrel's centre and the shears' head pulley), and thence overhead and into the shaft.

The capstan rope should be covered or housed as much as possible, so as to protect it from the deleterious effects of the

weather; and when it becomes, from any cause, in any way unreliable, it should be tested occasionally with a greater weight than is ever required to be lifted for the real practical purposes. It is much better to break a rope in this manner, when no other harm can result, than at a more inopportune moment, when the falling bodies might create the utmost havoc, or cause the loss of your "pumps," or even the lives of the workmen.

More than one instance has occurred, where an insignificant weight has broken a damaged rope, that would have borne, in its full strength, one thousand times the weight. A friend of mine was killed under such conditions, when nothing but the swing stage and himself were being sent down a shaft that required some examination and repairs.

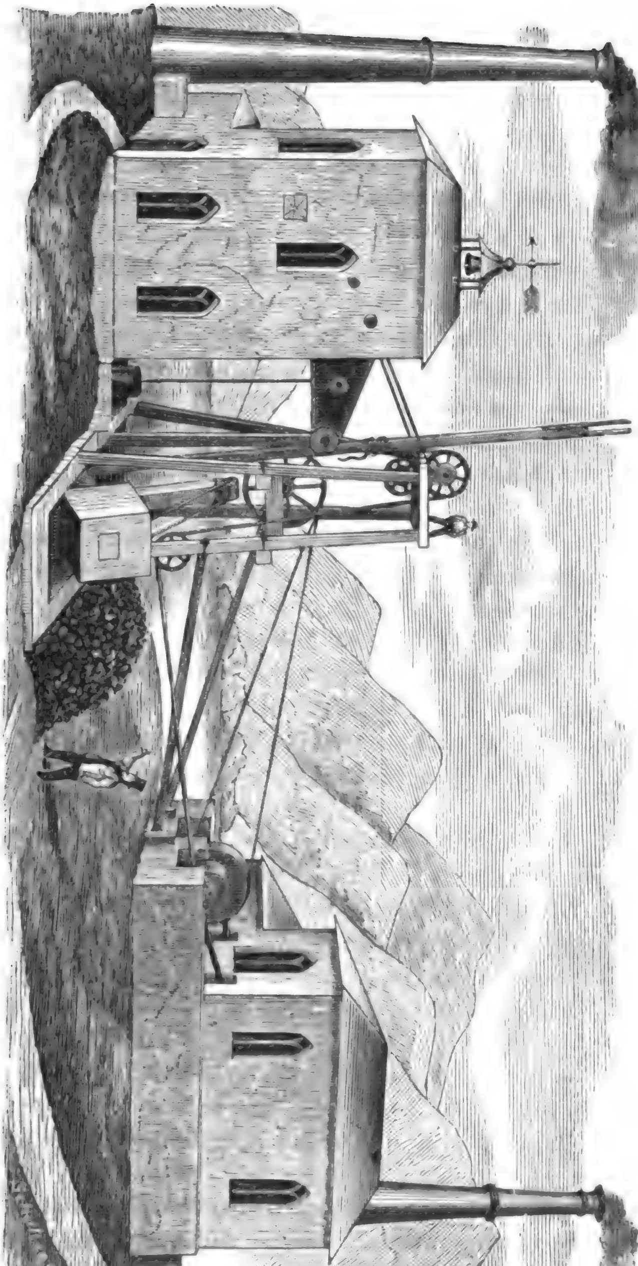
There is no particular advantage in the very long double-stick shears; and, where it is applied, the separate four-legged stand must be also had recourse to for hoisting purposes.

The arrangement shown by Cut 36 is trustworthy, serves all purposes, with much shorter and cheaper timber, and gives, in addition to the advantages already named, that facility afforded by the securing the hoisting bearers with "staples and glands" around the legs, for elevating the hoisting head as often as may be required for the heightening of the shaft burrow and shaft timbers, as the rock is drawn from the mine during the earlier stages of excavations both by the horse and steam whims.

THE CORNISH STEAM HOISTING ENGINES.—It has been stated that the Cornish pumping engine surpasses all others for pumping, for it is indeed one of the perfected wonders of man's mechanical ingenuity, as peculiarly adapted for this substantial purpose; but such cannot be said of their hoisting machines, for they have been as badly contrived for the work, in all their surface and underground appliances, as they were expensive in fuel; and it is but a few years since that the more observing Mining Engineers have given it any commensurate attention.

A certain type of such engines have been erected all over the county, which should serve as beacons for avoidance.

Cut 36.



View of Surface Machinery as Arranged for Pumping, Hoisting, and Capstan Works.

It will be therefore wasting space to describe them, any further than to state that they are single, condensing engines, which vary from about eighteen inches to twenty-six inches in the diameter of cylinder, and from about four feet to eight feet stroke; are of vertical action, carry steam the whole stroke (*with no expansion*), which enters and leaves the cylinder by four disk valves, as caused by tappet motions and catches, and regulated by a governor valve.

They are hand-worked by two handles, which can be seized at pleasure, as required for easing, stopping, reversing, or throwing retarding cushions of steam the reverse way when lowering the single bucket in deep mines.

Against this one advantage, thus so clumsily attained that it requires much practice to perform, stand very many disadvantages, which are not solely confined to the engine house; for, generally speaking, chains are used, which, working between the arms of horizontal or vertical "forked cages," are not only extremely noisy, but dangerous, as it is quite a common occurrence for such chains (which have several thousands of welded links) to break from imperfect engineering, en route of the kibbles through the shafts; for, not being guided, they have full, unrestricted sway, in their ascent and descent; many things combine to snap the chain, and frequent havoc and delay ensues, in spite of the greatest care of the driver.

Now the kibble hitches ere it leaves the plat; or the bed plank gives way, and it catches a sleeper; or they fail to pass each other freely, and the descending kibble is arrested and brought up, but to fall away; or the chain hitches between the angle rollers, etc., etc.; so that if the chain does not break, it strains and weakens, and the bucket arrives partially or wholly emptied; but, even worse than all these, the friction is so terrific, at all times, that neither fair speed can be made, nor quantity of rock be drawn from the mine; so that more shafts and engines must be applied than are really necessary.

It is amusing, as well as most instructive, to look back through life at these untoward delays, as seen by the light of the "lander's" lantern; for it is the general supposition that they happen most frequently at the worst possible times.

Trevithick, who first applied the steam engine to the railway and common road carriage, was a Cornishman; but, although he was engaged through his whole life in the mechanics of mining, he overlooked the application of rails and cars as guided through shafts, with the great advantages that have been since obtained by such subterranean railways; so that the miner continued to sink vertical shafts, to avoid these general evils. Some of the largest and deepest mines in Cornwall have no such railways, but still use these abominable kibbles, as drawn over the bed plank, or naked wall, by the noisy, uncertain chain; but, in all such cases, the men are as antiquated in their notions as their mechanisms are barbarous.

In later years, the founders, by becoming largely interested in mines, and being also coal merchants, have to a great extent, had things a little too much their own way, and all alterations of their patterns, or adoptions, are opposed; so that an engineer has but little encouragement for improvements.

Some years since, I contrived a very cheap and effective arrangement of gear, that could be readily applied to these very numerous four-valved, non-expansive engines, which should still retain their *one facility* when handled, and give them the much greater advantage of any degree of expansion when working alone.

It appeared the very desideratum against this crying evil and extraordinary waste of fuel, and should have been a profitable patented right; but not so, for, on consulting a leading firm, I was quaintly informed that it would not be to their interest to save fuel, and thus it ended in smoke.

The hoisting engine should have the following excellences.

1. It should perform the work with the utmost economy of fuel, by the continual expansion of steam.
2. Be capable of stopping or starting from all parts of the revolution, to suit all heights and depths.
3. Be able to move either very slow, or fast.
4. Be always within easy control, under all variations of speed, when elevating or lowering its load.

5. The levels and shafts should be provided with rails and wheeled cars, to facilitate the speed and economy of the engine, during the removal of the rock.

6. The shaft cars should work in pairs, for better balance and regulation of the work.

7. Provided that sufficient strength and these excellences are retained, the first costs, both for purchase and erection, should be as low as possible.

The best engines for obtaining *all these advantages* are the horizontal, double cylinder, expansive steam, condensing engines, as fixed and attached to right-angled cranks, at each end of the drum, for double draught, by wire or hempen rope, in the manner shown by Cut 36; and when the interest of the miner is considered, rather than that of the founder, they may be made and erected as follows.

The engine house and the outside loading are built of strong, hard, and heavy stone, up to the level of the wood bearers, on which the cylinders and outer stools are laid. This stone loading must have the necessary holes for the "holding down" or securing screws to pass up through, to fasten down the engine, etc., to the work. The sleepers that thus support the two crank stools should pass from one end of the work to the other; whilst the parallel pieces, that also form half of the beds for cylinders, should pass from the one end of the engine room to the other, so as to completely jam between the end walls, when they are screwed down on the bed-rock or loading, to obtain more permanent stability. The sleeper that supports the nearer end of the capstan stool should pass from one end of the stone work to the other, and be even more strongly secured down than the others, and its holding down screws should not be vertical, but their bottom ends should be dipping from the strain of the work of draught, which is never reciprocating; so that all endeavors to strain shaftward may be checked by the consequent tightening down of the diagonal screws.

The distance these bearers should lie asunder, will be of course, governed by your particular engines, as suitable to the depth of the mine, or whether you use wire or hemp rope; but in no case should the barrel be of less length than

five feet (unless the old-fashioned chain is used, which winds more frequently on shorter and smaller barrels), so that after the room required for eccentrics, capstan pinion, the stools, and the cranks, is allowed for in breadth, the cylinders should be at least ten feet asunder.

The hoisting barrel should not be less than nine feet in diameter for wire rope, nor less than five feet for hemp or chain; and the capstan barrel the same as that for hemp rope.

The whim-drum or barrel should be tightened or loosened from its axis by a "drag link" or a taper bolt, which may be screwed either way, for both purposes, at pleasure, when required to work the capstan or itself.

The driving pinion wheel for the capstan may be fixed on the winding shaft, and the rest of this part may be subsequently ordered, when required for actual use.

The nearer stool of the capstan must be swivelled, or the journal can be made of globular shape, whilst the further end is fixed so as to slide in or out of gear with the pinion.

THESE ENGINES MAY BE ERECTED FOR WORK in the following manner.

Fix the outside stools for hoisting axle in perfect level and line, at suitable distance asunder for the bearings.

Key on the furthest crank, and lay the *two* engine eccentrics on loosely; then key on the driving centre-piece at the further end of the drum, and just this side of the eccentrics; next place the barrel or drum on the shaft, fasten it securely to its centre-piece by its taper screw key, and next key on the driving pinion of the capstan, so that the drum may have a little side freedom; and, after putting on the other two eccentrics loosely, lift the whole into working position; and, lastly, key on the nearer crank, just square, or at right-angles with the other. Two keys in each are very much more reliable than one, as they afford triple resting-points against all varying strains, and can be more readily performed by ordinary workmen; whilst, by one key, the axle must not only be closely fitted to the holes, but the most skilled workmen are required, and much more care and time.

The crank axle may be next accurately squared to the

sleepers, and the stools firmly screwed down, then marked and better secured by letting them down about a half-inch into the wood.

The cylinders must now be fixed at the proper distance within the house (that the piston may clear equally at each end), at the exact height of the cranks, by cutting the wood down as before (with their slide jackets or boxes inside, towards each other), in exactly straight lines with the throw of the cranks.

These being all correct, the cylinders can be also screwed down securely

Place the slide valves into their working positions, on their edges (for they are thus contrived to be in direct line and position with their eccentrics, to avoid the superfluous gear that would be otherwise required), their bottom flat edge or side being widened to nearly the breadth of the box, to keep them in constantly better position against their vertically apertured, steam-tight facets.

Attach the spills to the slides, connect them with the double-slot link motions, place the valves exactly at half-stroke, and take the length of the eccentric rods by measuring the exact distance from the centre of the main crank-shaft to the connection pins' centres at the other end of the eccentric rods, and if their lengths are not correct, make them so, and then proceed to fix and key the eccentrics in exact positions for working the valves, so that the engines may work either way, as directed by the one or the other of their eccentrics.

This may be done by placing the nearer engine exactly on the crank's outer horizontal position, or on its *outer centre*, and turning one of the eccentrics the way the engine is supposed to go, until the slide valve, as governed by this eccentric's rod, opens the aperture just about three-sixteenths of an inch, to admit steam so as to provide for the piston's easiest propulsion; this is about the most effective advance for the steam's admission to such engines, and is called the "lead;" the exhaust, through the inside of the valve, should always precede this in proportion to the speed of the engine, as best known by the indicator's diagram, or from the practice of good makers. The lap of the valve should be such that it

shall in itself cut off the steam at five-eighths of the stroke (so that the engines shall be always in power); the steam will be much increased in its expansive action by being wire-drawn, as the previously filled jacket-full is being admitted to, and expanded in, the cylinder.

This eccentric is now tightened to the shaft by a temporary grip, and the other eccentric is turned round in a similar manner, but in the other direction, for giving the engine motion the opposite way, until it has also three-sixteenths of an inch "lead."

It will now be necessary to repeat the motions for the first eccentric, so as to *correct any error* that might have been caused by the then *unfixed*, and consequently *inaccurate position*, of the second eccentric.

This end being right for both ways, turn the crank to its *inside centre*, and examine *both* leads there, by again moving the slot link until each eccentric rod stands opposite the valve spills.

The "leads" should both agree with the three-sixteenths (as should also the sum of both ends equal three-eighths of an inch, in the examination of the leads at subsequent times, after the engine has worked some time); if the lead is more or less than this, the *new* eccentric, or valve rod, is too long, or too short, and it must be shortened or lengthened exactly the one-half the difference of the two end leads; thus, say that the first end "lead" was three-sixteenths, and the last five-sixteenths, the rod must be shortened just one-sixteenth of an inch, and the eccentrics be re-adjusted, to obtain the three-sixteenths lead, as advised. Then permanently fasten each eccentric with two keys.

Horizontal engines, which revolve but one way, such as for stamping, crushing, sawing, and driving machinery, should be set to travel so that the draught and thrust on the piston-rod cap shall in a manner float the weights of the ends of the piston and connecting rods over the guides, instead of increasing their friction by additional downward strain, which the pressure of steam would produce if the engine traveled the other way.

BY ANOTHER CONSTRUCTION OF PARTS—The engine may be much reduced in width, as the shaft of the cranks can be short-

ened to only just the length required for their cranks, stools, four eccentrics, and for *two* driving pinions; the first for the capstan as before, and the second for a similarly arranged axle and drum for hoisting the rock, either or both of which may be slightly bevelled, if necessary, to suit the direction to the shaft; whilst turn pulleys may be erected at some distance from the hoisting drum, to divert the rope for hoisting from other shafts, when necessary. This device may be worked by smaller and faster engines; but I prefer the former, where larger engines go round for round with the drum. A pair of eighteen-inch cylinders, of say six feet stroke, or a pair of quicker traveling fourteens, of four feet stroke, may be had, as either arrangement is adopted.

A pumping crank can be attached outside of the capstan drum's stool.

As but one of these wheels will be in gear at a time, that out of gear will require to be secured, and it is most readily done by screwing down an iron plate on the outer transverse wood sleeper, in such a way that it shall be common to both; so that either wheel being withdrawn by the screw for that purpose, it may be so arranged that its teeth will bite the stop-plate, as soon as it begins to move away from the driving wheel.

THE WORKING GEAR FOR HANDLING SUCH MACHINES—*Should be as simple as possible, so that the "driver" can perform the necessary motions with certainty, precision, and promptness.*

For these desiderata, the following arrangements of gear will be found well adapted.

About four feet above the slide valves' reversing slot links, and two feet nearer to the front window, erect a transverse arbor, on two suitable standards, and key a twenty-four inch horizontal lever on each end, just over, and connected by rods and pins with, these reversing slot links; then key another horizontal lever, of about the same length, in the middle of the arbor, to reach back towards the window, and place a movable weight thereon, to exactly counterpoise the valve attachments; this lever should have another limb, so angled as to form a right-angle with the line of rod next attached thereto, to lead towards the window, to connect

with a long vertical lever, that is to be used for starting, stopping, and reversing the engines, and which may be fixed on an axle beside the governor valve lever, which is also required for the admission of more or less steam to the engines.

The eccentrics should be so set (which may as well be done after this gear is in working position as before) that the hoisting drums, which are both seen through the window, shall follow the motion of the reversing handle.

The reversing and the governor handles should be contrived to stand at any position in certain numbered notches, that both serve to guide the driver as to the place required, as well as to retain it in such position during the hoisting or lowering times.

This guard for the reversing lever should be graduated from a central zero both ways, and should be arranged for being slidden the one way or the other, for the correction which it may need.

That for the governor must be marked but the one way.

A Brake Wheel may be Fixed within Reach—Although it will not be so much a necessity for these more manageable, instantaneous acting, double-powered engines as for the single (four-valved) engine, that has two handles, and which cannot be reined, *after certain speed* has been attained, from running away, during the too rapid lowering of weights.

A Miniature Shaft-board, to Represent the Motions and Relative Positions of the Wagons with the Surface and the Bottom of the Shaft—Is an almost indispensable auxiliary for most speedy draught; for, being continually before the eyes of the driver, he can hurry the wagon almost to the surface, and anticipate the sound of the lander's bell to the very moment; thereby saving very much time, with even greater safety than otherwise.

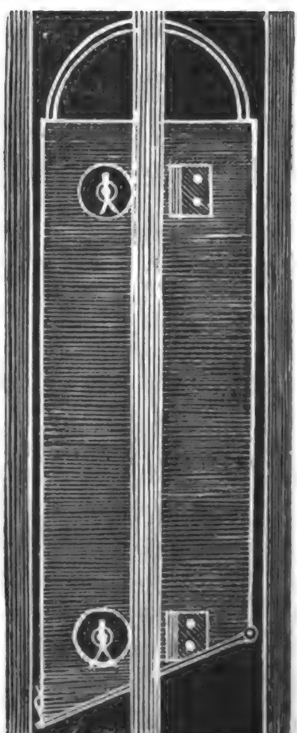
Some of the best modern mining engineers of Cornwall have now introduced shaft railway wagons, instead of kibbles, which are hoisted by either twisted iron wire, or hemp ropes woven flat or twisted round, in place of the much more noisy and uncertain iron chain, which is used only for a few feet near the wagon, where the rope would be too speedily worn away.

When wire rope obtains fair usage, it is much cheaper than the others, takes much less space on the drum, and works even better; but it requires peculiar treatment and suitable mechanisms.

The hoisting cage, as previously stated, should not be less than nine feet, and the shaft pulleys must be from ten to twelve feet in diameter; the connecting sockets of the rope should be supple and light, yet strong; the pulleys smooth and plentiful, and the rope must be kept slippery and free from rust, by a mixture of tallow, plumbago, and coal tar; which is laid in long troughs under where the rope sags between the pulleys.

Shaft Railways—May be made in four or five different ways.

Cut 37.



1. *For vertical shafts*, two single continuous (square) wooden rails may be attached to cross bearers, one on each side of the shaft, to merely guide the car, which has two pieces of flat iron simply riveted on to each side of the wagon, near its top and bottom, so as to loosely grip the rail, as if within finger and thumb; whilst the body of the car guides itself transversely.

2. Two pairs of rails are extended from the bottom to the top of the shaft, and *one* thin metal plate is riveted on to the wagon, which, intervening the double rail, guides the car.

3. *Where the shaft is inclined both ways*, eight wheels may be used, four over and four under the *one* pair of rails; or, *secondly*, double rails may be used on each side, whilst half this number of wheels work centrally between rails.

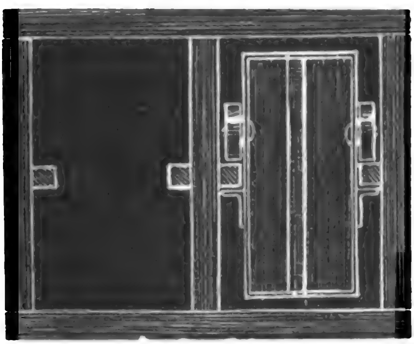
4. *Where the shaft is both vertical and inclined*, the better

plan is to have the four wheels over a pair of single rails, and flat guides under, which are of little good on the incline, but *serve to stay the twist*, during vertical travel. (See Cut 37.)

5. *Where the shaft is far from perpendicular, and entirely inclined*, four larger wheels may be used over the rail, over the upper half of the car, which will be sufficiently safe in action, provided the body of the wagon nearly fills between the rails, which will then serve for effectual side guides.

In all cases, the wheels should not be less than eight inches in diameter, but, in the last instance, from twelve to sixteen inches, and four or five inches wide; they must be plain and flangeless disks, and be hollowed out as much as is consistent with strength; their wrought-iron axles may be from one and a quarter to one and a half inch in diameter, riveted thro' square holes in the malleable iron wagon's side, as supported by a broad outside collar, the wheels being kept in position by a washer on its square end, which is safely secured by a split key, as shown in the accompanying illustration from an end view of the one side of the shaft, car, axle, wheel, washer, split pin, rail and cross sleeper, flat iron guide, etc. The bow should be shaped and swivelled to turn on one side when the car is being filled.

Cut 38.



Of course, where double cars are used, the middle cross sleeper must carry the double set of rails.

When the side room is fully economized, a five feet wide shaft will convey a pair of cars which will be, when also made long and deep, sufficiently capacious for most of the purposes required for metallic mineral mining; but coal mines will require much larger cars, or a cage whereon one or more cars from the levels can be run on to its rails, and again run off when hoisted to the surface for dumping, where it is most desirable to do so.

For the more general and ever-varying requirements of extensive mining from *many levels*, the cars with hinged

bottoms, as illustrated. will be found most serviceable, which receive rock by being lowered on to a movable stop to the particular level that requires to be cleared, where the shaft should be contracted to a funnel mouth, just to suit the car, for convenience and greater speed in filling, and to prevent the rock from falling into the shaft.

This wagon may be either filled by a somewhat smaller car being brought from the level and tipped therein, or the rock may be dumped into a "tip plat," for being shovelled into the shaft car, when required, by one or two boys or men, who must go from level to level for the especial purpose. *This is the more favored method for the general purposes of the miner.*

When the car reaches the surface, it lifts a tranversely hinged and diagonally hung sheet-iron door, which, by falling as soon as the car is at proper height, serves to guide the rock into the surface wagon, when the securing pin is disengaged from the hinged door or bottom of the vertical wagon.

The "tip plats" are excavated in different places, to suit circumstances, hardness of ground, position of pump work, cistern, etc.; but, as a rule, they are better to be cut out from the foot ground, so as, by curving the rails slightly, the rock may be dumped from both ways into the same plat, just opposite the one or both "skips."

To regulate and facilitate the general operations of winding, a "knocker" is hung at the mouth or surface end of the shaft, which is merely a horizontal iron lever, that carries at the one end a hammer that strikes upwards under a piece of sheet iron a certain number of times, as worked by a vertical wire, which descends through the whole depth of the shaft, within convenient reach of these working plats, etc.; so that certain orders may be given from those below to the surface men, as before alluded to in the explanation of the pumping engine; for instance, three knocks means hoist, two knocks lower, and one stop, or any other, as may be arranged for especial communication.

The fillers may also, and frequently do, inform the landers when the plat is emptied of rock, by securing a piece of wood to the draught chain, etc., which may also inform him by a suitable number of notches, or pre-arranged signs, as to th next level from which the rock is to be drawn.

Bells are used in the houses of the hoisting machines, to which horizontal wires extend from the shafts, to inform the drivers what must be done. The best kind of bell for this purpose is known in England as the "Yorkshire;" it is so constructed that by the aid of a spring and catch, it strikes but one for each pull of the wire; it therefore articulates more distinctly than the common bell, and cannot be misunderstood.

MAN ELEVATORS (MAN ENGINES).—In the working of deep mines, the labor performed in the descent and ascent by the old style ladder-climbing was not only disagreeable and dangerous, but by far the most tiresome to the muscles, and deleterious to the constitution; so that this serious deduction from actual physical energy and strength of the men not only disabled them from doing the really substantial duties that are imperatively necessary for profitable mining, but occasioned great waste of time in its very performance.

The men, rather than climb this distance, will frequently risk their lives by riding up in the rail-wagon, although it is most peremptorily prohibited by the agents, and club rights are forfeited to those who do it.

The man elevator is contrived to ameliorate these conditions; but, although exceedingly safe, effective, easily constructed, and moderate in cost—in fact, financially beneficial—it has been but too rarely applied.

The manner for its construction and application may be described in a few words, as follows.

A rotary and expansive engine, of suitable power—say from twenty-five to thirty inches diameter of cylinder, and some six or eight feet stroke—is applied somewhat after the manner for pumping, when slow motion and consequent power are increased by teeth-wheels. The large wheel being provided with a crank, the wood rod, of say eight inches at the surface and gradually less below, is attached thereto, properly balanced by a balance-box, and stayed in such a way that platforms may be attached at every ten or twelve feet asunder, from the top to near the bottom of the shaft; whilst corresponding fixed stages are secured to the side or end of the shaft. Now the stroke of the crank, of course, agrees

with these distances, and therefore, if a man steps from the fixed stage to the movable platform on the rod, he will be carried up or down, accordingly; whilst a sufficient number of repetitions will carry him to the surface, or to the bottom of the mine. The motion of the rod is regular, and he merely steps in a sideling manner, as he stays himself on or off, by suitably placed hand rails for that purpose.

Two rods may be applied, when there is plenty of room, where, the one platform being up when the other is down, no fixed stage is required, and the speed is doubled, as you are traveling downwards or upwards continuously, without interfering with each other. This is the better of the two; but the single rod is cheaper, and can be the more readily applied under usual circumstances.

The first man engine erected in Cornwall was in the year 1843, at Tresavean Mine, then 1680 feet deep, where some four hundred miners were transported most joyously to the surface daily, at a cost of but one-fourth that of climbing ladders, with immeasurable comparative ease and comfort.

As compared to the system of elevating men by rope, this machine does it for just one-fifth the cost. The first cost ranges from about $5,000 to $10,000, which would be saved during the first year's use in deep mines, where many men are employed; but this is but trifling, as compared to the extra ease of, and consequent work performed by, the miner underground.

Its advantages may be, however, best measured by a glance at the miners as they arrive at the surface, after the actual climbing of ladders, and when brought by machine.

TRAM ROADS, OR HORSE RAILWAYS—Should be always used, instead of common roads, when the surface of the ground permits, as one horse can do just as much as two, in the conveyance of ores to the reduction works or floors, which are oftentimes at a distance from the shaft or tunnel's mouth, on account of the greater facilities afforded from better site, water-power, etc.; and sometimes even steam is used to a great advantage, for still cheaper conveyance to the otherwise costless power.

In such roads, a rail should be selected that permits of

being readily fixed in small cast-iron stools, and of such shape that the rail may be turned over when worn out of shape on the first side, so as to obtain double wear.

The line should approach the shaft or level in a transverse manner, so that car after car may be filled by being moved on under the tip from the mine car, to prevent the cost for shoveling as much as possible; and, on arriving at the mill, the same facility may be adopted for discharging the several cars. By this arrangement, one man or boy may drive several horses, to make one, instead of several, journeys.

In large mines, double lines of rails may be used, for greater comfort and expedition, as ample time is allowed for the filling and emptying of the wagons, and delays from the turn-points are entirely prevented by this additional outlay.

A cheap locomotive engine may supersede horses, when still further distant, or where horse-feed is dear and fuel is cheap; and sometimes a canal may be used to great advantage, where the ground and water will permit.

Small wagons may be contrived, either for tipping their contents over the end or side, or both ways, by a suitable *horizontal swivel under the middle*, so that their *vertical acting hinge* may face either the *ends* or *sides*. The larger wagons are generally emptied with shovels, or by having their bed-planks drawn out from under the rock, which falls into the slide that leads to the dressing floors, crusher, or battery.

Where mills are at moderate distance and on lower ground, which they often are, a double-track road may be laid down, which, being headed by a suitable reel, or barrel and brake, the full wagon may, by its descent to the mill, hoist the empty wagon from the mill to the mine. It may be so arranged, too, that as it strikes a lever at the bottom of the grade, it shall dump its rock into the mill, etc., without assistance.

At other times, it will be found more convenient to have the cars drawn on a single—or, better, double—track, of suspended chains, or rails, so that two following wheels shall travel thereon, above the cars, which are attached by straps; all being drawn or floated along above the ground, in mid-air, under the tracks.

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CHAPTER V.

DEEP MINING, AS FACILITATED BY SUCH MACHINERY.

In Chapter V of Section II, and in Chapter II of Section IV, the prospector and the miner had partially exposed and more fully examined the vein for its value; which we will suppose is quite worthy of being developed for realization of its riches in the full *mining* sense of the word, to its deepest sections; and will conceive and confront in our minds the different successions of excavations, mechanical appliances, etc., that will have to be performed in the general working of mines, and apply the necessary means to accomplish the many requirements that may arise, during such probable contingencies.

To illustrate this, we may as well take the mine as left by the Examiner, at the end of Chapter II of this Section, which is supposed to be worthy of being wrought, and is sufficiently well suited for our purpose of exemplification.

The first, most important duty of the Mining Engineer, previous to deeper development, is to fully satisfy himself that the shaft is in the best possible position for the centre of the dip of ore, (as illustrated by Cuts 4, 5, 6, and 7, and explained at pages 88, 89, 90, 91, 92, 93, and 94.)

This shaft was sunk to take the lode at a few feet below the adit; for, in the first place, it was required for ventilation; and, secondly, for hoisting the rock thus high for tipping into a car that was to convey it through this level to the reduction works, so as to save unnecessary hoist, etc. The exact depth where the engine shaft should strike the vein depends on circumstances; but, in this case, it could, for the reasons given, be no better placed.

If no adit or drainage level had been driven, it might take the vein deeper, as say at the top of the deposit of profitable

mineral ground; but, wherever it is preferred, it is frequently modified by preliminary mechanical difficulties, such as placing the "fend off" (or bell-crank lever), to turn the action of the main rod from the vertical to the diagonal or dip of vein, which should be in a position to be fixed before the water becomes too much for barrels, or much extra trouble and expense will be occasioned thereby.

It is therefore but seldom that the position selected for our example will be very much in error, in these earlier virgin developments, before the more exact positions, dips, and extents of the mineral deposits can be more correctly ascertained; if *more than one shaft* should be required, such vertical or diagonal shafts may be sunk in the very best positions for mining the vein with the greatest possible economy.

The mine having exposed ample evidence that it contains more water than can be drawn by ordinary means, and sufficient mineral to warrant the necessary outlay for both pumping and hoisting machinery, you may proceed as follows.

Cut out from the foot rock a suitable recess or bed for the cistern which may receive the water from the present barrels, and act as a reservoir for its more regular discharge into the adit level, to run from the mine; it will be necessary, too, for receiving the future water from the pumps, and (unless surface water can be readily obtained for feed and condensing purposes) for the reception of an upper set of pumps (called the "*house lift*"), for supplying feed and condensing water to the engines, and a suitable excess for the other purposes, as washing and treating ores, etc.*

Next, the necessary ground should be cut out from the hanging wall side, for the double-limbed "fend off beam," or bell-crank lever, that must be made when pumping power is required; and it can be more readily done now than after the shaft has been sunk deeper, when it has been fitted with the appurtenances for hoisting, pumping, etc.

The length of this lever should be at least one and a half times the length of the stroke of the main pumping rod.

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* As an approximate rule, the size of the "house lift," or pump for the feeding and condensing water, etc., of a Cornish pumping engine, may be found by dividing the cylinder's diameter by 10; that is, an 80 inch cylinder engine will require an 8 inch pump; but this pump is generally made larger for other purposes, as dressing the ores, etc., etc.

The works of cutting ground for cistern and "fend off" being accomplished, fix the cistern in position for convenience in discharging the water from the barrels, as drawn by the horse-whim; and set the shaft, at a fair price, to six men and three boys, to be sunk for at least one month, or as much longer time as they are willing to accept and are able to perform the contract, which may be worded as follows.

"The engine shaft to be sunk on the course of the lode, by six men and three boys, for one month (or for ten fathoms, or sixty feet, or other distance), or until the water shall exceed say ten barrels per hour, to be carried at least fourteen feet long by five feet wide within timbers, which must be fixed therein by the contractors, if necessary to do so to support the ground in a mining-like, substantial manner. The takers must provide all necessary materials, and fill their kibbles; and the Company hoist the water and the rock, by horse-whim, from them to the surface, as required."

Being fully satisfied by the increase of water, and mineral indications, or mineral, that more power will soon be required for its removal and realization, you may place a few surface men to clear out the foundation for the hoisting and pumping engines, after the manner illustrated by Cut 36. The hoisting engine should, however, be a little further removed from the shaft, so that the ropes may traverse more freely, and be less liable to ride untowardly on the drums.

The drawings of the engines, foundation, etc., unless given by yourself, will be sent from the foundry, and this house may be built and the engine erected as explained at page 390.

The *foundation* for the pumping engine's house may be also marked out, so that the house may be built, the engine erected, and the boilers placed to supply them with steam.

This is a time for the application of considerable judgment as to how much water and what size pumps will be required; which is governed by the size and extent of the fissure, its spurs, intersections, etc.; by its general, comparative, basin-like position, and the cleavage of the particular country rock in which it lies embedded.

The granites contain less water than the limestones and slates, being much more compact and water-tight, from more

solid texture and greater freedom from layers of stratification, joints, etc. It is well to estimate by comparison with your neighboring mines, when you can do so; and it is customary to so arrange the size of pumps that the Cornish pumping engine may work at this stage but about from one to two strokes per minute; the engine, too, should have sufficient excess of power, looking to the deep future, to realize the greatest economy from the superlatively beneficial point of cut off for the expansion of steam.

Calculate as closely as you can, from the quantity of water being drawn, and these other collateral reasons, what sized pump, of say nine feet stroke, will be required for ridding the mine of its water, at the initial speed given; and the size of the cylinder for the Cornish, direct-acting, *wheelless* engine, may be known in the following ready manner.

Take an engine (as the best for efficiency) of ten feet stroke at the cylinder, and nine feet at the shaft-end of the main lever, and say a ten inch pump is required of such nine feet stroke, to work at the rate of from one to two strokes per minute. To ascertain the proper diameter of cylinder to pump water from 2400 feet deep, with such a ten inch pump, you may figure from the basis that a ten inch *cylinder engine* will be the proper economical size to work a ten inch pump sixty feet deep, under the boiler pressure of fifty pounds per inch (or any other size of engine against an equal pump).

The comparative direct elevating power of engines, under similar pressure, is governed by the square of the diameter of the cylinder; so that as sixty feet is to the *square* of ten inches (or any other) diameter of cylinder, $10 \times 10 = 100$ *superficial inches*, so is 2400 feet (or any other required depth) to the number of *superficial inches* of the required piston, the square root of which will give the diameter of cylinder required, which is figured thus: $\frac{2400 \times 100}{60} = 4000$ superficial inches of piston, the square root of which gives nearly sixty-four inches for the diameter of the required cylinder.

These pumping engines have been made of certain sizes only, which range from a 36 to 40, 50, 60, 64, 70, 80, 90, and 100 inches for Cornish uses, and of 144 inches of cylinders as made for the peculiar purpose of draining the Harlaam Lake, as explained by foot-note at page 379; so that should they

ever be ordered from them, these sizes must be observed, or the engine, by requiring especial patterns, will cost much more.

We will therefore suppose that the size of our pump is ten inches, the cylinder of the engine is sixty-four inches diameter, the maximum travel of the piston is ten feet, and that the pump has a nine feet stroke. We have therefore sufficient power to elevate ten strokes of water per minute by this engine, from the depth of 2400 feet; whilst, in the meantime, the engine is economizing fuel under lighter load.

Now, for reasons given, the length of the inner end of the main lever of such an engine will be sixteen feet eight inches, whilst the outer or pumping end will be fifteen feet.

The centre of the cylinder does not lie under the centre of the inner pin of the "bob" or main lever, when the latter is at half-stroke, but exactly half of its vibration, or in middle position between the half and the whole stroke, so as to average its total travel; and such is also the case with the centre of the main pumping rod, as regards its pin's centre; so that these half-vibrations must be known before the house and cylinder loading can be marked out in a correct manner.

It may be done by figures or construction.

1. *By figures.*—Square the whole length of the inner end of the beam; then, after squaring the half of the length of the inside stroke, subtract the latter from the former, extract the square root of this result, and subtract this root from the whole length of the inner end, which remainder, being then divided by 2, will give the half-vibration required; and the whole length, less this amount, will be the distance from the centre of the cylinder to the centre of the main lever wall.

Thus, the inner length of beam of 16 ft. 8 in. =	200	inches.
Its half-stroke of 5 feet .... =	60	"
Now the square of 200 inches..................... =	40000	"
The square of 60 inches.......................... =	3600	"
The difference of these squares .... =	36400	"
And the square root of this difference....... =	190.78	"
Now the sum of 200 and 190.78 .... =	390.78	"
And this sum, divided by 2..................... =	195.39	"

Which is the correct distance from the centre of the main lever wall to the centre of the cylinder, being 16 feet $3\frac{3}{8}$ and $\frac{3}{32}$ inches.

The distance from the centre of the main lever wall to the centre of the main rod may be found, in the same way, to be nearly 14 *feet* $7\frac{1}{8}$ *inches. And so for air-pump and feed-pole rods.*

2. THE VIBRATION MAY BE FOUND BY CONSTRUCTION—By taking a plank of somewhat greater length than the beam's centres, and drilling holes at the exact length; the *one hole* must have a round bar snugly fitted therein, to act as *the central pin*, when the beam is moved over the *horizontal ground* in imitation of the real stroke of the engine; whilst the other end is drilled to suit a pencil or metallic scratcher, which describes from the beam's radius an arc of the proper sweep for rather more than the length of the stroke, on a suitable transverse board.

Insert a pin at one end of this arc, and another pin near the other end, just exactly at the extreme length of the stroke, and straighten a thread from the first to the second pin. The greatest right-angled distance from this line to the arc will be equal to the whole vibration, and this, being measured by rule or compass, may be transferred to the plank representative of the main lever, to reduce its length thus much; whilst, at the half of this vibration, a hole may be drilled through, to serve for future measurement when marking out or correcting the foundation, and during the building of the main lever wall, cylinder loading, etc., in suitable position at the proper distance from the main pumping rod.

Construction is the most efficient and certain method, as it is so easily ascertained and used, that errors cannot occur; it also measures the lesser strokes, and it is available for all men.

We may now consider the size and position of the main pumping rod, as it hangs under the half-vibration of the outer end of the main lever.

THE SIZE OF THE MAIN PUMPING ROD—Is governed by the size and power of the engine, and the practice of Cornwall has been to make them from squared sticks of Baltic pine,

of one-fifth the diameter of the cylinder, or twice the diameter of the piston rod, which latter is one-tenth the diameter of the cylinder. They are also made of American pine.

These should range from sixty to seventy feet in length, or longer if they can be obtained, so as to save as many connection plates of iron as possible.

Much better rods than these can be procured from New Zealand (the "Cowrie pine"); and splendid octagonal twenty inch rods were obtained for a one hundred inch cylinder engine that was erected at the Great Wheal Vor Mine, Cornwall. They were upwards of one hundred feet in length, of equal texture, free from knots, of very straight grain and growth, and altogether of superlatively surpassing quality.

THE POSITION OF THE MAIN PUMPING ROD—Is a matter of much importance; and perhaps, looking at all things, it is best placed in the corner of the shaft that is furthest from the hoisting end, and nearest to the engine house; in our case, the size of the rod, by the rule stated, should be about twelve and seven-eighths inches, and its nearest side to the engine should be far enough from the shaft's side timbers to permit of the iron bolts being placed into, or removed from, the wood rods and the iron "strapping" or connecting plates, without bending the bolt, which is sufficiently long to go through the wood, double irons, and its securing nut; so that in this case, the nearer side of the wood rod should be at least seventeen inches from the engine's side, and just as much from the end of the shaft, for similar reasons; *but if the balance beam and box are placed at the end of the shaft, as shown by Cut* 26, sufficient room must intervene for the proper clearance of the balance beam's connection rod, which is stapled to the side of the main rod, at some sixty feet below.

The easier and safer way is to lay down a platform over this part of the shaft, so that it may be used as a kind of "drawing board," for the full-sized representation of the necessary lines.

Having ascertained in this manner the correct position of the main rod, take a nail, and, after first passing it through the hole of the plank at the half-vibration of the outer end of the beam, pass this plank, which represents the main

beam, in over the site for the engine house, and, when properly supported on stools, square it exactly with the shaft walls, and drop lines from the holes at the centre, and at the half-vibration at the inner end of the beam, and the points of the plumb-bobs will be just in the centres of the main lever wall and the cylinder.

The length and breadth of the house is somewhat varied, to the taste of the manager, cost of stone, etc.; but in no case should it be less than the following, which may be marked out from the size of the castings of the engine, etc.

Draw a cord of indefinite length transversely across the plank that represents the main lever's position, through the centre of its main gudgeon, and mark out this wall's width according to the breadth of the cast-iron bed-plate (that is forwarded to rest on this wall, under the stools which are keyed thereon in suitably dove-tailed grooves), half inside and half outside of this line, allowing about a foot outside of the wall for clearance from the wall. Now, for the other end and side walls, if you have no cast-iron girder that is made to reach from wall to wall, nor drawings from the foundry, you may strike a horizontal circle of the exterior size of the cylinder (say five feet eight inches), and mark out the inside lines for the *end and side walls*, at least four feet beyond this circle, so that the inside breadth will thus be at least thirteen feet eight inches. The thickness of these walls may be three feet, and again about one foot may be allowed on the outside of each wall for clearance.

Drive wood pins down at each extreme outside corner, and excavate the whole intervening prism of ground to a suitable depth for obtaining a trustworthy foundation for the walls.

The ground is now ready for the masons; and as soon as sufficient stone, lime, and conveniences are on the spot, you may set your contract, and begin to build the house. I must just now call your attention to a horizontal line that may be seen just above the ground, which extends around the house of the pumping engine, in Cut 36, which is a reduction of size called the "set off;" and here commences the true wall, as stated above; so that if you prefer having the wall about six inches thicker below this line, which is a good and almost general practice, you must allow for it accordingly. I prefer

having it both outside and inside of the walls, as it then provides a step or rest for the bottom floor, which is also at this level.

These walls may be now built up with granite, or other strong stone, to about two feet high of solid masonry, excepting a small hole under the middle of the main lever wall, for passage of any accidental water, or for a man to attend to the holding-down bolts of the condensing cistern and work; which, in these engines, are always thus placed without the building.

At this height, it will be necessary to make a frame of wood, in which holes must be drilled to exactly correspond with those of the cylinder's bottom, which receive the holding-down screws (whose collective areas across their weakest sections around the key-holes must equal that of the piston rod).

This is properly centred under the inner "half-vibration," and the building of the cylinder loading, which extends from side to side and to the back wall of the house, and as far towards the shaft as the flange on the said bottom of the cylinder, excepting that two narrow "crows," for a man to get in under where these "holding-down screws" are to pass down, is left unbuilt upon. Two or more strong granite stones are now laid across these "crows," and holes drilled therein for the holding-down screws, exactly under the holes as made in the wood frame, and which must be slightly larger than the bottom ends of these screws.

The whole house and loading must be now built to seven feet high from the foundation, taking particular care that good runners and headers are built across each other in the wall and in the loading, and that the loading shall tooth into the end and side walls, and lock itself in the same manner. Square wood pipes may be fixed over the holes for the holding-down screws, to save the expense of drilling holes through the strong stones that may be crossed the one over the other, and around these pipes instead, which, thus made, are stronger than otherwise.

At this seven feet in height, a three and a half feet wide window or doorway must be commenced in the middle of the main lever wall; and then the whole four walls, with the

loading, may be built up to say twelve feet above the foundation (this depends upon the *height of the loading,* which is never made *less than twice* the diameter of the cylinder), finishing the top of the loading with one or more large stones of granite, which must be cut to a *somewhat* truthful level top. This is not strictly imperative, as the cylinder would then vary as it was tightened down; so that the practice is to adjust the cylinder by the insertion of thin iron wedges upon the stones, under its bottom. The wall is now brought to a level, and reduced to proper thickness to form the outer and inner set off.

The reduced walls may be now built to the height of the main lever wall, taking care that the front opening, that was commenced a few feet under the floor, is still continued to a proper height for forming a doorway to the condensing cistern work, and over this to the shaft; that two side openings are left for the windows, and a *large arched doorway* at the back, whence the road leads, and where the *beam and cylinder* must pass in through to their working positions; not forgetting the opening for the cross girder, which carries the anchors for parallel motion, and on which the "spring beams" rest, as they pass from the front to the back wall, and rest on all, to receive the occasional "bangs" of the engine during ordinary working, or to save the bottom of the cylinder at any time of serious breakage, as the main pumping rod, etc.

The top of this opening, which is about three feet square, should be about the same height as the top of the main lever wall, and the side that is nearest to the lever wall should be about three feet further towards the back wall than the inner "half-vibration's" vertical line. This, however, may be more correctly ascertained by adding the *excess or difference* of the length of the radius rod over that of the parallel bar of the parallel motion, to the depth from the centre of the anchorage pin to the extreme side of its iron stool, which is sometimes secured to the side of the wood girder.

An especial iron beam or girder is often used, to run from wall to wall in front of this wood girder, for anchoring the radius rods, which may be drawn full size on a board as it is intended to work, as governed by the above *difference*, or

excess beyond the vertical half-vibration line, when the true advanced position of both the iron and wood girders may be known.

The height of the lever wall from the top of the loading can be ascertained by measurement and summing of the several connections from the centre of the inner pin of the main lever to the centre of the piston; and then, after adding this total to the *distance from the centre of the working part of the cylinder* (when the cover and bottom are on), *to the outside of its bottom*, that rests upon the loading, and deducting the central height of the stools which are to rest on the main wall, for supporting the main lever.

Or, in other words, if the height from the bottom of the cylinder (or the top of its loading) to the centre of its internal working space is seven feet, the distance from the centre of the piston to the centre of the cross head is fourteen feet, and the main loop (or connecting link) is five feet, these added together will equal twenty-six feet; and if the main stools are four feet high to the centre, this, being subtracted from twenty-six feet, will leave twenty-two feet for the height of the main lever wall above the top of the cylinder loading. To this height should be added the intended clearance of the piston from the bottom of the cylinder, which, being four inches, then makes it twenty-two feet four inches.

The top of this lever wall must have a layer of wood securely bolted together, the full *outside* breadth of the house, the width of the wall, and eight inches thick, to form an adjustable bed for the stools; of course this wood must be included in the stated height of twenty-two feet four inches.

The side walls can be now built thereon, and run up with the end wall for some twelve feet higher, and roofed over.

The openings for the side and end windows must be continued and terminated some distance above this level, so as to give light to both floors.

This is, however, a novel arrangement, to save windows and to strengthen the walls; they are generally made at the three floors.

Two openings must be now made through the back wall at the sides of the window, for the spring beams, at about three inches above the level of the main lever wall (the thick-

ness of its bed plate), and the same distance apart from centre to centre as the stools for the main lever's gudgeon, the under parts of which are made hollow to receive these spring beams.

The roof may be now put on, and the masons transferred to build the flues beneath the boilers, so that they may be laid thereon; when the surrounding flues and walls of the building may be finished, and also covered by a suitable roof.

The lever end is closed up with thin wood, and a circular centre-piece around the middle of the beam keeps the rain and wind out from the engine.

In this arrangement of windows, the lower windows enlighten the bottom floor, and the upper windows the half-floor that is placed on suitable beams around the upper part of the cylinder, as well as the upper floor, which rests on the spring beams, and which extend the whole length of the main beam, within and without the house, not shown in the cut, because it would hide the other parts, that are now distinctly seen.

THIS CORNISH PUMPING ENGINE MAY BE ERECTED in the following manner.

In the first place, provision should be made that the heavy parts of the engine and the boilers shall be brought into the mine the right end first, and be unloaded as nearly as possible to where they are required.

Every part of the engine, except the condensing work, has to be passed in through the "cylinder end" doorway, and it is therefore first necessary that a bed of whole timber should be laid down on the acclivity of approaching ground, for them to slide over, on suitable cradles, or upon rollers.

Two good hand-winches must be procured; and I have found it better to have one of *single power* made expressly to suit the breadth between the spring beams, to be fixed thereon for present and future use indoors, and the other a *double power*, to be moved, when necessary, from place to place, for outdoor use, which may be fixed on runners of half-timber, and loaded down as much as is necessary to keep

them steady, just opposite the front window, and in line, to work either overhead or through this opening.

The outside winch being fixed, first hoist on to the *top of the wall*, over the main lever wall, four transverse pieces of strong ten or twelve inch whole timber, in pairs, so that a suitable distance may intervene, for making room for the upper block to pass up into this recess.

Now lay on to the top of the wall four similar transverse pieces of wood, immediately over the cylinder's position.

Take the length from the inside of the back or cylinder wall to the outside of the main lever wall, cut four pieces to this length, and lay them fore and aft the house, upon the first laid transverse timbers, one within two feet of each side wall, and the others near the middle, about three feet asunder.

Lay on these two other layers of transverse pieces, similar to the first, but shorter, to suit the roof, etc.; and, lastly, upon all these place short and strong fore and aft pieces over the cylinder and lever wall's centre, to carry the chains that support each pair of blocks for lifting the various parts.

By this important arrangement of the pieces, you will provide against the *rolling* or *sliding* of the timber, during *oblique-angled draught*, have *strong suitably positioned supports* for the *two heavy weights*, and by a *sliding piece over all*, a pair of blocks may be *readily passed to plumb over all requisite parts* of the house.

Being thus provided with head timbers, you may firmly secure, by very strong rope or chain lashing, the two upper four-sheaved blocks over the cylinder's and lever's central positions, reeve them to connect by six inch white ropes with their bottom blocks, and lead the falls to and over the barrels of their respective winches, and obtain suitable nipping chains for the winches, which should not be too short; about fifteen feet long will be enough for fastening to the one side-frame, and on the rope; thus, about ten feet of straight chain will intervene from the one to the other, when the rope is retained by this lashing until the slack rope of the fall is transferred to the other end of the winch barrel, for repetition and further elevation of the weight.

The carpenter must now prepare two spring beams, which

should be sufficiently long to extend from the outside of the back wall to the outside half-vibration over the centre of the main rod, about fourteen inches deep and as wide as the stool; and a third similar beam, to be vertically cut in halves, to form two lesser beams, that must run parallel to the spring beams, and conform to the side walls, for supporting the transverse floor, which extends for the whole length, both within and without the house, to the outer main connection. Also, the transverse girder, which may be made either of one piece of wood, or of four or six pieces bolted together, of a size, for such an engine, of not less than two feet six inches deep by two feet wide. These being made, the carpenter should proceed with the outside work, as the cistern for condensing work, the shears, the balance beam and its box, main rod, etc. (as shown in Cut 36), and the underground "fend off" beam.

Now the first part that will be required for the erection of such an engine is the large flat bed-plate that supports and retains the main lever stools in their proper places.

This may be brought into the house, and hoisted into its position by the outside winch and the overhead block, and adjusted to the centre of the top of the wood frame on the wall. If it suits badly on the platform of wood, it must be hoisted, and the wood trimmed where necessary, by an adze, until it lies evenly, when, after a thin coating of lime cement has been plastered thereon, it may be lowered and spiked or screwed down to its place, through holes which are cast in the plate for that purpose.

The two spring beams (which pass under and through the hollows of the fore and aft stools), and their corresponding and parallel side beams which lie against the wall, may be now placed into position, so that the top floor can be laid thereon for greater safety.

The fore and after hollow stools and their supported pillow blocks are next hoisted and keyed in their true concentric positions, as to straightness with the house, height, and proper distance asunder to suit the shoulders of the main gudgeon, taking especial care that about *an eighth side play is allowed, as this slight sideling circulates the oil, and prevents the journal from grooving*, during continued wear.

As there will be no chance for subsequent adjustment of these parts, they must be accurately keyed into position, which is facilitated by their make; as the hollow sub-stools are keyed between fore and aft "lugs," whilst the upper pillow blocks, that really carry the brasses, are transversely dove-tailed and keyed into concentric line, between other suitable ribs, which are cast on the top of the bottom stool.

A plank should be cut to the size and shouldered shape of the main gudgeon, and the long piece that you were recommended to use when marking the foundation and during the building of the loading, nailed across its middle in a square and central position, so that it may represent the real beam, which, being applied to the stool as the real gudgeon, will provide the means for informing you, by the aid of lines dropped from the holes that were drilled for the positions of the half-vibrations, if the stools are correct for carrying the piston and main rods, as intended. This cross should be inverted, and the lines again dropped, for better proof, which will correct the cross when not made quite square; the true place being midway from the first and second trials.

Whilst these stools were being adjusted, the first half of the "bob," main lever, or beam, should be drawn into the house by the outside winch, the pumping end first, through the cylinder doorway of the back wall, over wood rollers (which may be cut from round timber), to within some eight feet of the main front wall.

Two half-pieces of ten inch round timber should be now jammed between the main stools, with their flat sides down, and overlaid with flat iron, the one piece being close to the outside, and the other near to the inside, of the wall. These are intended to form suitable rests for the separate halves of the beam, as they lie at proper heights on their edges, previous to having their main gudgeon and other pins put through their respective holes, which are generally inserted and keyed after elevation, to save the lifting of the whole weight, which, in our case, is at least some thirty tons.

It is much better to key it together on the ground, and hoist it in complete working order, if your gear and winch power is sufficiently strong.

In this example, as I intended to illustrate the lifting of its separate pieces, in less weights, the spring beams and floor were fixed, which they should not have been if the beam had to be lifted with pins and gudgeon complete, as the latter would not pass between; upon these spring beams other similar sized but shorter pieces, called "banging timbers," may be laid, which reach from the furthest side of the cross girder to and just through the hollow stools, where their ends are shaped in an ornamental manner upon the spring beams, and keyed down by other wedge-shaped pieces, that are driven therein by a battering ram through the stools. A single-power winch (six feet wheel on a nine inch barrel, driven by a five inch pinion), which should be supplied with the engine, and made to suit the breadth of these beams, may be now screwed down (by bolts that go through both the beams), just over the cross girder, as it will serve for this lift and the future inside purposes.

THE LIFTING OF THE MAIN LEVER FOR THE LARGE CORNISH PUMPING ENGINE—Is considered the most difficult mechanical feat in mining engineering; and "much ado about nothing" is frequently made, for want of firmness, system, quiet watchfulness, care, and consideration of the laws of forces. Although it is generally a scene of great excitement, and sometimes a perfect Babel of noisy confusion and profanity, it may be performed much more easily in solemn silence.

Attach the main lever block to the one side of the pumping pin hole, by at least six turns of five-eighths best chain, double-knotted, and the surplus ends stop-knotted or bolted through the links, to prevent all possibility of slip.

Attach the cylinder block to the main gudgeon holes of the *same side*, in a similar manner.

Call your men together for manning the winches, *which should have a safe maximum number of men, who could not, by too much strength, break the rope;* select therefrom two trustworthy hands to attend to the nipping chains, and your orders as conveyed by intelligible signs, which are as follows. *For hoisting*, one arm is elevated to the vertical position above the head; *for lowering*, it is passed down from the shoulder to the knee; *for stopping*, the hands are to be

clasped before you at mid-height; *for nipping*, the hands are revolved the one over the other, before your person, at breast-height; whilst, for *increasing* and *diminishing* the speed of either winch, the one hand is moved in a transverse circle to the observer, very fast or very slowly.

Now these being all *speaking signs*, are not likely to be misunderstood; and as one winch is without, and the other within, the house, you can only face the one party whom you wish to instruct, so that the other will not alter their work in the meantime.

After making sure, by a short rehearsal, that your men will sustain the programme, you may ascend to that side of the top of the lever wall furthest removed from the half that you are lifting, where you have full sight of the work, cordage, and winches, and give your orders as described.

Your first duty should be to cast your eyes along over the whole appliances, to see if your main block is just over where you want the first half of the beam to rest, when hoisted upon the wall; then if there are a sufficient number ot turns—say eight—in each of the upper chains, and if they have proper length of spare ends beyond their knots to prevent accident, in case of a slip; if the ropes depart fairly from the block sheaves; if they lead straight to the winches; if the outside winch has sufficient loading, staying, etc.; if both have good nipping chains; if the ropes are properly reeved through, and secured to, the eyes of the blocks, and wound at least four times around the winch; that the ropes are held back to tighten on the barrels, by a couple of trusty men at each winch; and that the chains on the beam are lashed in a manner not to run through the holes, during the necessary side strain that will be in action during the turning of the beam on its edge.

These things being perfectly satisfactory, I will anticipate what will be required, and give orders accordingly.

Facing the inner winch, order them to hoist (by the elevation of the right arm to the vertical position); as the strain comes on, the eye of the block surges a link or two in the chain lashing; then, on further hoisting of the block (unless the chain is disposed to slip through the hole), the upper timbers give audible creaking evidence that the strain

becomes more considerable, until the several pieces are visibly bent, and the blocks begin to lift the beam's side from the ground.

Stop the inside winch for a few minutes (by clasping the hands); and, facing the outside winch, order them to hoist (by hoisting the arm to the vertical position); as soon as the outside winch receives strain, give the signal for the inside winch to hoist, and slow the outside to just keep their rope to moderate tightness. When the beam becomes nearly vertical, if the central chain has not allowed the eye of the block to slip sufficiently, both the winches may be stopped, and the beam stayed securely by shores from the side of the cylinder door opening, whilst the inner winch is lowered a little to free the eye of the block into a central position, the men keeping their hands firmly on their handles, whilst the two men hold heavily back on the rope, in case the shores should give way.

After the block is corrected, hoist the inner winch until the full weight is again received, and carefully "nip" the rope with the chain that has been attached to the side-frame for the purpose, by knotting the other end to the rope, and slacking back the winch until the rope on the barrel becomes *free from strain*, when it must be moved across the barrel for another hoist, the *back-holders* being always provided for any accidental slip that may, but should not, occur; hoist this winch to receive all the weight, *then stop*, and "nip" the outside winch rope in the same careful manner.

Hoist *both* winches together, and slow the *inner one* when the pumping end of the lever slackens the outside fall, being always mindful that the inside blocks should bear nearly all of the weight, or the narrow half of the main lever will be liable to turn over.

The end of the beam is now just clearing over the edge of the *iron* bed-plate on the wall, and the lower end is about entering the doorway below, and just now care should be taken that the whole weight is borne clear of the ground by the inside winch, or it will suddenly surge over the foot-stone into the house.

As soon as it enters the house about eighteen inches, a square piece of timber should be thrown .. · oss the opening

behind the end of the beam; and both blocks, particularly the inner one, may be lowered until the nose of the beam muzzles into the loading, then stop the winches, and wedge securely from behind, and shore the sides of the levers half from wall to wall, in such substantial manner against sliding and turning, that no possible accident can occur.

Next shift the lower chain lashings; that from the centre back to the lower end, and that from the upper end back to the middle of the beam; and carefully examine that none of the links of the chain are injured in any way.

As soon as these chains are securely attached as before, set taught both blocks, and nip each winch, *one at a time*, before the shores are removed, so as to have fair start.

Hoist on both winches, with much watchfulness, and keep them free from slackness of fall; for if the inner fall slackens, the end of the beam, by rising therefrom, is free to sway sideways, and therefore the outer block, by drawing so obliquely and endwise from the top edge, is very apt to first swing around the last end towards the side wall, and then turn the beam over on its side, which not only creates danger, but causes much trouble to rectify. If both are kept at proper tension, this will never occur.

This most critical point being passed, the beam is soon hoisted to its full height, and into a position that is just opposite the opening of the stool; and now the half-beam may be lowered at proper side distance on to those transverse iron-faced half-timbers that were intentionally placed to receive it, which will also prevent it from touching on its middle; for, being round, it would be not only unsteady, but too low for the insertion of the main gudgeon.

The inner end of the beam is next supported by a chain from the upper timbers, and shores are extended from the stools and side walls, to places which will not interfere with the hoisting of the second half of the beam or the gudgeon, that must be hoisted for insertion into the central hole of the first half, and passed nearly through to make room for the hoisting of the second half in exactly similar manner, the whole of which may be easily accomplished in a day.

The second half being placed exactly opposite, the gudgeon is run backwards into both; then the other outer and

inner gudgeons, with feed and air-pump, plug-rod, and motion-pins, being also entered into their places, the distant pipes are next dropped down between the half-beams, the bolts are passed through and screwed until the two halves become just as safe and secure as one beam, which, after the journals are all keyed, it becomes.

The whole beam is next lifted, the brasses dropped into the stools, when the former is lowered into the latter, and a whole piece of strong timber laid across from spring beam to beam, to support its inner and heavier end to a *dead level* position.

The top of the heavy stones that form the loading may be next chiseled to a level, the cylinder bottom placed thereon and screwed down temporarily, and the cylinder drawn into the house on a cradle made by two full-length runners of half-timber, on which two transverse pieces are bolted and hollowed out to suit both length between the flanges and the circle of its body, which is then lifted on to the bottom and bolted thereto, for preliminary trial as regards being level, and exactly under the half-vibration and transverse positions.

The most speedy way is to first level the cylinder by wedging up the bottom from under, and dropping a plumb line from the centre of the beam just at the centre or the half-vibration, and directly measuring how much it has to be moved the one or the other way, and keep leveling, moving, and adjusting until it becomes exactly correct.

There are two ways of leveling, the one by a straight-edge and spirit-level as applied across the top, and the other by a plumb rule or staff, that extends from the top to the bottom of the cylinder; but I prefer the last way, as it frequently happens that the end is not true to the inside boring, by imperfect workmanship, from irregularity of the iron of the casting, both as regards shape and porosity, and sometimes from the shifting of the cylinder during the different strains occasioned by the cutting tool, etc., etc.

In using the former, the straight-edge and level must be checked by turning them the reverse way; whilst, in the latter, a fine thread should be used, and the same side of the straight plumb staff be held against the cylinder as you travel from quarter to quarter, so that if any error exists in

the instrument, it shall, by being reversed on the opposite half, check itself. A plentiful insertion of thin iron wedges should be tightened under the bottom, which must be screwed down firmly, and the cylinder reëxamined, to see if it has swayed from truth.

The piston rod may be now keyed into the piston, and after a lead tube is coiled upon the inside of the bottom of the cylinder, to protect it from fracture under accident, it may be hoisted into the cylinder, the cylinder cover put on, and after the parallel motion and piston cap or cross head are attached to the main lever, the piston rod may be hoisted into the cap, and keyed by the enclosing and enclosed annular half-rings, as especially contrived for this engine.

Previous to the hoisting of the piston rod, it should be marked just on the level with the top of the stuffing box, so as to observe how much the lift exceeds the half-stroke, which must be no less than four inches for clearance of the piston from the bottom of the cylinder, at the extreme limits of its descent.

The catch eyes may now be placed on their projecting bosses, outside the inner end of the main lever, and the horizontal catch-bar (which is about the extreme breadth of the spring beams, ten inches deep and two inches thick), passed through the upper deep eyes that are purposely made to receive it, and keyed firmly therein; it is now ready for being bolted together sideways, and stayed from behind by diagonal tie-bolts from the back link-pin of the parallel motion.

Hard-wood "banging" or stopping pieces are now spiked on each spring beam, at just the half-stroke of five feet under this cross catch.

By this time, the masons will have built the walls that are intended for the supports and bottom flues under each boiler, which are at proper height and lie sufficiently apart (say thirty inches) for these purposes; and your spare men, now relieved from the inside heavy work, may roll the several boilers into their places.

The inner side of the first boiler should be fourteen inches off from the side of the engine house wall, the several boilers twenty-eight inches distant from each other, and the outside

wall fourteen inches, as each boiler requires this breadth for separate and complete flues at the sides.

If the steam pipe holes are cut, of course they must be opposite to the steam pipe; but otherwise, the front ends of the boilers may be about fourteen feet back from the front wall, which has as many coal slides for supplying fuel as there are boilers to consume it.

At the other (back) ends of the boilers, the walls should clear the boilers about five feet, for the turn of the flues, dampers, etc.

These boilers are, as stated, cylindrical, and have also an internal cylinder, in which the fire burns. They are from thirty to thirty-eight feet long, and from six to eight feet in external diameter, the internal fire tube being from three feet six to four feet six inches.

A cast-iron *fire door frame* is screwed on at about fourteen inches from the end of the boiler; the intervening space, through which the gauge-cocks pass, being built up with bricks to come just fair with the face of the front.

The men may be now employed in hoisting the cross girder into its place; helping the carpenter to lay the beams for the floors; getting the top and bottom nozzles, with their vertical pipes and steam pipes, into their places; and making the joints between the cylinder and bottom and flanges of the nozzles.

At the inner end of the fire-place, a brick bridge is built, which stops the under portion, and causes the flame and heated gases from the fire to pass close to within one foot of the top of the boiler tube, and back through the tube to return by two flues, now built by brick arches against each side of the boiler, to the front of the boiler, where the flue being turned down to unite with the single flue, the gases pass down to concentrate the heats of these colder gases into the one bottom flue, which pass thence to the chimney.

The damper frames and dampers being built into the work at about one foot from the back wall, the hollows are filled in with sand or fine earth to the level of the top of the boilers' fittings. The dampers are worked by cords, which pass over rollers to the front, where they are balanced to work easily, and may be stopped and retained at any point, by a series of holes in the vertical handle, as placed on a pin.

The masons may now build up the walls for supporting the condensing cistern, and after laying thereon a suitable bed of wood and the cistern, extend them up its sides, to serve as a loading for this bed, to which the condensing work is fastened down by screws, which may be attended by way of the man-hole at the foundation of the front lever wall, previously alluded to in building.

The air-pump and condenser may be now fixed in correct position, with the exhaust pipes from the engine by way of the bottom nozzle, as generally adjusted to length by a spigot and faucet joint.

The boiler walls may be now built, and the roof put on; when the spare erectors can place the boiler fittings, and connect the steam pipes to proper position.

The joints are not all made metal to metal by lead putty, as this would be most inconvenient for this scattered engine; but are sometimes of the more accommodating kind called "spigot and faucet," or the flanges are brought to butt on narrow interior ribs, which keep the outer and larger portion of the connecting flange about the varying distance of from one-fourth to one-half inch asunder, between which either the old time-honored "iron rust" (which is a mixture of one hundred parts of iron rust, sifted through an eighth-inch sieve, and one and a fourth parts sal ammoniac, just sufficiently moistened with water to set well), is firmly caulked, by a thin, flat-ended caulking steel; or the modern mixture of red lead putty with *linseed* oil, solidified during the caulking, by throwing a little of the sifted iron in, as necessary. Both should have fair time to rust or set firmly. (The law demands that retaining bolts shall be also used.)

The latter is the easier in execution, and has the great advantage over the former, that either a steam or vacuum joint may be caulked again and again, if necessary to stop subsequent leakage. Whilst the joint-makers are about this work, the other spare hands can key on the air-pump bucket to its rod, and put it into the air-pump barrel; place the foot-valve into its diagonal working position between the pump and condenser, the valves on the air-pump bucket, and the "swimming cover" valve on over the air-pump rod and barrel (which works at its head), and pack its stuffing box; fix

the guide for this rod; take its length, by hoisting the bucket and rod to about two inches above the half-stroke, and after the rod is made to the correct length, connect it with the main lever.

The feed "plunger" or "force" pump is generally made so as to be screwed down on the top of the condenser, which may now be also attached, with its valve-box, valves, and pipes to connect with the hot well and the pipe that runs in front of the boilers, under their several governing and anti-return valves. The plunger pole must be next dropped into its place to the bottom, and being then hoisted to about one inch above the half-stroke, the length of its rod may be taken, made to correct length, and also connected with the beam.

The governing and stop-feed valves may be attached to the front of the boilers, on the side of the fire tubes, at about two feet under the surface level of the water in the boilers.

Two gauge cocks are generally used, without gauge glasses, which are placed at about four inches and eight inches above the top of the fire tube, and the water is supplied to range from the one to the other, as governed by the whiffing of intermittent steam, as the top of the water approaches the one or the other; but this affords insufficient margins, and is very unsatisfactory and unsafe, as it is a common practice to allow the water to get above the top cock, and sometimes even below the bottom, when indiscreet fools run fearful chances that the water is at safe height, and awful explosions result. It is therefore almost imperative that a third cock be used, at about one inch above the tube that shall indicate the exact commencement of danger, when, if the water does not increase, it shall be criminal neglect of duty if the fire is not immediately withdrawn.

It is still better to have four gauge cocks, the fourth being placed some four inches above the third, to give an occasional advantage for knowing where the water is, where an extra quantity is required for cleansing the boilers, or previous to stopping the engines for many hours.

Glass gauges are very good collateral checks, for careful, intelligent drivers, or for steamboat and locomotive boilers, where the water continually *oscillates* in the glass, and by

which the pipes may be known to be clear; but for boilers that are perfectly steady, and fired by *such men as are generally selected for working engines on mines*, who would be too apt to rely entirely thereon, and thus, thinking that it would *continue forever faithful*, explosion would be much more likely to occur than when gauge cocks kept them continually responsible and *regular* in more alert habits.

Drivers should invariably gauge the water before firing, and open *all* the gauge cocks at least *once in each shift*, so that they may turn freely when required for unusual and extreme purposes.

The steam "stop valves" may be next put on to each boiler, and united to each other and with the engine by their appropriate steam pipes, which are generally ordered from the foundry to suit; but, when in remote positions, they must be made of correct length, and the boilers brought to suit the pipes before they are built over by masonry.

The safety valves are now put on at about the middle of each boiler; and, for greater safety, there should be *two valves* to each boiler. The valves should be large, as they are liable to stick; for, whilst their *adhesion* is governed by the *simple diameter*, the upward pressure *to free it* is as the *square of the diameter*.

See that the gear and pins are very slack, for workmen are so addicted to good fits, that nineteen times out of twenty they will be too tight for this safety purpose. It is not their business, but yours, to discriminate when it is so highly improper. Brass pins should be used in preference to iron, as they will never be liable to *rust* or *jam*.

You should also calculate the pressure of steam for your own satisfaction, as occasioned by the size of valve, length of lever, and the accompanying weight, by squaring the internal diameter of the valve in *inches*, and its *decimal parts*, which will give the number of circular inches, and this being multiplied by .7854, will give the number of square inches of the valve as conventionally required for pressure. *The weight should be also weighed, for greater certainty.*

Now, if this weight was put exactly over the valve, and the steam began to escape, it would be of just sufficient pressure to lift it; so that the weight being divided by the

number of square inches in the valve, it would give the pressure that was being exerted per inch by the steam; and if the valve was but one square inch, the weight would at once be the pressure. So that supposing the same weight was again placed at any distance still further out on the lever, and the pressure of the steam was increased until it again lifted the valve, the pressure would be increased in proportion to the leverage; or if the valve contained sixteen square inches, and the length from the centre of the pin to the centre of the before-named point immediately over the valve was five inches, and the length from the centre of the same pin to the *centre* of the weight (which is say one hundred pounds) was fifty inches, it would be figured thus: The weight of 100 pounds, multiplied by 50 inches, and divided by 5 inches, would equal the pressure of 1000 per inch, if the valve was but one square inch; and of course, when this 1000 is divided by 16 square inches, it will be 62.5 pounds per square inch. These are suitable dimensions for this maximum pressure. The weight of the lever is disregarded.

The blow-off pipes remain to be fixed, just under the front ends of the boilers, which are about four inches in diameter, and elbowed to run the water straight away through suitable culverts, that are made for this express purpose. One boiler may be cleansed at a time, which should be done at least once in six months, by washing all the water and mud out through this pipe. It is a good plan to have also (although rarely done) a tap in this pipe, which can be opened by a lever occasionally, in the meantime.

The boilers may be filled with water to the upper working cock, the man-hole branches put on, and all the upper joints made, when the boiler is ready for firing slowly for drying the flues.

The plug rods may be next attached to the beam, and the guides, tappets, slides, etc., put on for working the hand-gear, which must be placed and keyed on the arbors that work in vertical columns called weigh-posts; then, after the valves are placed in their positions in the nozzles, their covers jointed on, and their working levers fixed on the top of the nozzles, the rods may be connected to the hand-gear before named, which is on the bottom floor.

The valves are now balanced by levers on the arbors, which connect by vertical rods to appropriate boxes beneath the floor; whilst another lever also connects by sub-arbors beneath the floor with the injection valve that is attached to the one side of the condenser.

Lastly, the slip-catches are fixed, and their "cataract," or *time-keeper*, which causes them to slip at the desired times, for faster or slower working, as previously explained when describing this engine.

Before the radius rods of the parallel motion are attached to the anchorage block or bar, or these placed to correct position, it will be better to pack the piston, screw down the cylinder cover exactly central, make its joint, and pack its stuffing box, which will cause more correct centering of these parts.

To fix these anchor and radius bars in the easiest and best manner, it will be only necessary to bring the parallel and the radius bars of the motion to an equal level, and then wedge the girder to agree with the anchoring block or bar, as either is supplied.

When the iron girder is supplied, an arbor is also fixed that runs across the whole breadth of the motion, and rests on vertical screws that arise out from the main iron girder, which may be elevated or depressed by nuts over and under, to suit the level of the parallel bars; whilst fore and aft screws, that pass through suitable eyes in this arbor, can be also regulated by nuts; these screws pass through the large wood girder, and are firmly screwed to connect therewith for greater stability.

The one end of these radius rods is often made for adjustment by nuts on the bar, which lengthen or shorten the rod as it passes through an eye in the transverse bar, when it will be necessary to calculate for its length, which is done as follows. The distance from the main beam's centre to the centre of the back link-pin is squared, and then divided by the length of the parallel bar, which will give the length of the radius rod sufficiently near for your purpose.

Before the upper timber is removed, the shaft shears should be elevated to its position, as it can be done much easier by its aid. The chain lashings may be brought from the main

cross girder up over these timbers, to give the blocks good height.

Whilst the men are adjusting and keying the various gear; clothing the cylinder, nozzles, and steam pipes with felt, or other non-conducting materials; balancing the valves, and fixing the other general appurtenances; making the several cover-joints, packing the stuffing boxes, and clearing the timber away from above, excepting just four pieces that must be left over the cylinder cover: the pitman, timbermen, and shaftmen should be erecting the balance beam, connecting it to the main rod by a wood rod of from fifty to sixty feet in length, which is generally made of the same size as the main rod, secured thereto by staples and glands, that snugly enclose and tighten them on an intervening piece of timber of similar breadth, and of some six feet in length; the top end is connected to the balance beam, at half-stroke, by side strapping plates and brasses, in similar manner to the main rod.

It has been the practice to attach the bottom end of this rod at the distance that plumbs under the half-vibration; but this is an error, as the sideling action that is then produced on the main rod produces a most destructive jarring strain, that may be almost entirely removed by the proper obliquity of this rod towards the main rod, by reduction of the thickness of the filler.

If a line be drawn from the half-vibration of the nose-pin of the balance beam to the centre of the next "stay"-hole for the main rod, it will pass through the point of space where the centre of the bottom end of the connection rod will jostle the rod but little; and therefore the size of the intervening piece may be known by measuring from this line to the side of the main rod, at each end of the intended filler piece, and then deducting half the diameter of the connection rod from each measurement for the thickness of each end of the wedge-shaped filler.

The centre of the "stay" alluded to must be exactly under the half-vibration of the outer pin of the main beam.

Other main rods must be attached as required, and enclosed at about their middles with *thin hard-wood wearing pieces*, to work in similar "stays" or guides.

Before these rods are sent from the surface, they should

have holes drilled at both ends, as marked by appropriate templates that are kept for this express purpose; whilst the upper end should have the "strapping" or connecting plates bolted on, for more speedy connection to the rods that are already in the shaft. (See Cut 36, where they are in the act of lowering a main rod into the shaft.)

As the rods are kept to close abutment by the pressure of these plates on the side of the rod, and by the snugness of the bolts into the holes, they should be screwed very tightly, and be fitted snugly into the holes; the heads of the bolts and the nuts should always be made square, for this and all other shaft purposes, as the wrench is less likely to slip; and the bolts should be sharpened to centre punch points, so that they may be driven into, and out from, the holes with greater ease.

As soon as the country rock becomes of settled strength, a very strong set of *deep* stays should be fixed around the rod, by cutting "hitches" or recesses into the rock on both sides of the shaft, to receive the ends of a sufficient number of strong pieces of timber to make about say eight feet deep and eight inches wide on both sides of the rod, so as to form the "*sills*," or butting stop bearers, for the prevention of accident during a too long and speedy descent of the main rod, which is as much a necessity for this kind of engine as the catches that have been already fixed in the engine house, for staying the too speedy and extended inward motion of the engine.

THESE BEARERS FOR THE SHAFT CATCHES—Which in this case are also made to act for stays, may be completed for the double duty by having two wings (the one on either side of the rod), of about say eight feet long, and the breadth of the rod and thickness of the stays, firmly screwed by some six or eight staples and glands to the main rod, so that they shall strike on the "sills" when the top of the piston is still some four inches from the cylinder cover.

The shaft must be now fitted with the other appliances, as the "house-lift," or plunger force pump, for supplying feed, condensing and dressing water, which may be, say eight inches, in diameter; the best place for which is immediately

behind the rod, as worked by a parallel wood stock or rod, that is wedged into the cylindrical pole by being shaped to size, and driven by a battering ram until the one end gets on as far as the shoulder that has been left for it to stop against, and the other end is just fairly through, when, after it has been wedged quite water-tight, it is ready for use.

The flat-bottomed wind-bore (perforated suction pipe) is now lowered into the cistern, the **H** piece jointed thereon, and the pole-case, with its stuffing box, jointed on this, into which the plunger is concentred at proper half-stroke and clearance height, and its stock screwed on to, and in line with, the intervening filler and main rod. The eight-inch upper "clack"-piece being placed on the top flange of the other side of the **H** piece which lies along the side wall of the shaft, towards its corner that is farthest removed from the whim-shaft, capstan, and ladder ways, when the pipes are reared to the surface. The positions of these are all illustrated by Cut 39; so that this corner is now filled by the balance connection, main rod, and pump, whilst the opposite corner serves for ladder-way; which is also within reaching distance of the comparatively large and convenient capstan-way, for the conveyance of the heavy parts.

In this arrangement, the door of the **H** piece, for the insertion and occasional examination and repair of the valve or "clack," should be at the end, or a suitable recess must be cut in the ground, to create the necessary room for the changing of the clack.

A screw and chain should be also suspended over, and attached to, the doors, for facilitating the swinging off, and replacing them on to, the valve-boxes.

The mechanical appliances of the shaft being thus far completed, we will now prepare for fixing others for working the deeper sections below this level, around the angle into the diagonal shaft.

The temporary ladders may be now removed, and the footway fitted up in a permanent manner.

Ladders should be made of some straight-grained wood, of not less than thirty, nor more than fifty, feet in length, from four to five inches wide, and from two to two and a half inches thick; the ladder "staves," bars, or steps, should not be less

than ten nor more than twelve inches apart, and be either entirely made of three-fourths or seven-eighths round iron, or of oak or other strong (barrel-shaped) wood, with three locking staves of iron, one at each end and one at the middle, so as to securely retain the sides by transversely split keys.

There is much difference in ladder-ways, as to comparative ease in climbing, which is chiefly governed by the length, difference of distance between staves, angle of incline, proper number of staves above each platform, and that of easy transition from the head of the one to the foot of the other ladder.

As to the length, three ladders to the one hundred feet are good distances, each being thirty-seven feet long, so that the last step to the platform shall be as easily attained as possible by this extra height. The average of men will prefer the staves to be ten and a half inches apart, and the incline to be about three feet on this thirty-seven, which can be readily obtained in the perpendicular part of the shaft by placing all of the ladders one over the other, dipping the same way, the passage from one to the other being as shown by the arrow in Cut 39. It will be well to take a little out from the ground, just to make room for the shoulder, or to place the ladders somewhat obliquely with the way, as shown in the cut.

On the incline part of the shaft, the ladders will, of course, be reversed, to follow the dip; but should still keep sufficiently near to the capstan-way for occasional convenience when the weights require clearance, etc.

To illustrate all the difficulties which may occur at this point, we must suppose that much water has been just now cut in the shaft, which is but some ninety feet below this level, and the shaftmen are released from their contract, in consequence of this increase.

On the supposition that the profitable depth of the district commences at three hundred feet, we had better proceed as follows, to rid the shaft from water.

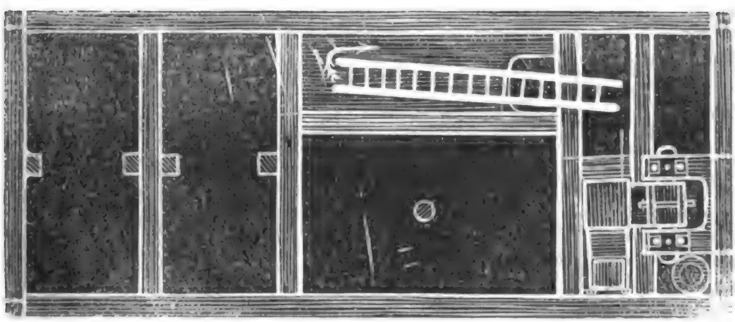
First, as the water is rising, lay on the foot-wall shaft-frame a slide of bed planks in the capstan-way, to facilitate the hoisting and lowering of the heavy and irregularly shaped pump work to their suitable positions; unless the bed-rock is hard and smooth, and this part of the shaft is not timbered, when it will be unnecessary to do so.

Then fix strong cross-bearers from foot-wall rock to hanging rock, entering into both for strength of support, and sufficiently far apart for the pump to pass down through these bearers into the shaft below, so that it may be securely stayed and lowered into the water as required.

If your steam capstan is now ready, you may screw or joint three or four pieces together at the surface, and lower them, all ready for work, into position below; but, if not, first send down the "wind-bore" (which must be of egg-ended shape for sinking, and sufficiently strong to resist the bombardment from rocks during blasting, which is, in hard ground, terrific, and requires a thickness of some three or four inches to withstand the shocks).

To this "wind-bore" (perforated suction pipe) is attached the "clack seat-piece" (valve-box), which is about four feet in length of expanded middle, with oblong side-door, for fix-

Cut 39.



ing and examining the valve, which is made of half-inch thick wrought-iron, to which a face of leather is riveted; the valve is hinged on one side, and generally works from a fixed centre; but sometimes the hinge rises into two slot links, about three or four inches high, which affords better clearance for the passage of the water, so that the front of the valve may not rise so far.

"Butterfly" double valves are sometimes used for large seats, which work on a transverse bar in the cast-iron or brass seating. The face of the seat is either quite flat, or rises at the middle, forming separate diagonal planes, which are illustrated at page 442.

Ample space should be allowed for the water's free traverse

through the seating and around the periphery of the valve, so that it may work easily. It is a good plan, too (as it gives the double advantages of suiting a larger pump for the future, if required, and present freedom for water), to have this "clack seat-piece" of one or two inches larger size than the pump barrel.

A bar of wrought-iron should always be fitted into the upper throatway of this valve-box, just at the level of the flange, to prevent the bucket dropping into the valve-box, and to provide a stop and support for a "drop clack," in case of accident to the valve of the bottom box.

Upon this the working barrel of the pump, which should not be less than fourteen feet long, and in our case, of ten inches in diameter, may be now screwed on (or, first, a short *taper* seat for "drop clack," if preferred); and then, being lowered, until the wind-bore enters the water, it is reared by pipes to the height of the cistern, and is ready for work.

There are some five or six ways for raising and lowering the pumps.

1. By a pair of powerful underground blocks.
2. By a long screw placed on and between the bearers, as worked by a long lever, on its nut.
3. By a pair of yokes, which together encircle the pump or pipes, and rest across the bearers, so that they may be made to retain or lower the pump, by more or less pressure on the screws.
4. By the steam capstan.
5. By the engine itself, by being securely attached to the main rod set-off or catches by strong chains.
6. Light lifts may be dropped as required, by having several turns of a strong chain reeved around one or more substantial pieces of timber.

The best and most frequently used means are those of the screw, or pair of strong blocks, as aided by the occasional grip of the yokes; which answer all purposes, for pumping out old re-worked mines, or for the sinking of new shafts. The former requires the whole weight to be kept in continual suspension, as lowered to suit the deepening of the surface of the water; whilst the latter requires but to be occasionally kept entirely or partially clear from the bottom of the shaft.

Now, after the wooden discharge lip (or "collar launder") is jointed on the top pipe, the bucket may be attached to its several rods by "clasp joints" (where *shouldered* or *stepped* square iron ends, that fold over each other for a few inches, are enclosed by a closely fitted, somewhat taper square iron ferrule), and lowered into the pump. (See Cut 40.)

The pipes that stand above this working barrel of the pump should be nine feet long, and one inch larger than itself, so that the bucket may pass down freely; and two "matching" pipes may be of use, the one of six feet and the other of three feet in length, to accommodate the height for discharging into the cistern.

To work this inclined pump from the vertical main rod, you may fix a temporary pulley on cross-bearers, so that a strong chain may be attached to the rod, which, by passing under the pulley, will, when fastened to a suitable "nipple" or iron pin on the main pumping rod, by an eye in the top end of the bucket rod, work the diagonal pump, to elevate the water into the "house lift" cistern, when all excess over that required for the engine, etc., will pass away through the adit level.

To accommodate the length of the iron "bucket rod," three means are resorted to.

1. The upper end, that is attached to the iron pin of the set-off from the main rod, has a long piece of flat iron, in which there are several holes.

2. The upper end has a strong chain, composed of several long links, so that either may be hooked on to the "set-off," according to the length required.

3. The bucket rods are disconnected or unclasped, and taken to the smith's shop as often as is necessary to be cut for lengthening by welded additions.

If you have but one smith or forge, the rods may be easily and much more safely welded, by building the forge and anvil exactly in line with the door of the house, and knocking a hole in the same line through the wall at the other side of the forge; the rods being first shaped so that the one may V into the other, are placed on suitable horses, or held in proper line by men, until they are at a welding heat, when they are driven to close adhesion by a battering ram, and

then promptly withdrawn in the same true line to the anvil, for being further hammered, to close down the points of the V scarf, and to reduce the rod to proper size and shape. For rods above two inches in diameter, it is the safer and easier way, even in the hands of good blacksmiths, and much more so with an indifferent workman; in fact, a mere novice may unite bars of iron in this manner, if he will remember to finish the operation on the anvil as directed, and to repeat the heating, if necessary to do so.

To obtain good and reliable union of iron, the fire should be free from lead, antimony, sulphur, etc., the iron be at the proper temperature, and the faces to be united should slide the one on and into the other, as if being kneaded into perfect intimacy, similar to putty, or flour and dough in bread-making.

"Butt"-joints that are not thus worked are unreliable.

This pumping part being now ready for the engine, you may fix the rails in the hoisting end in the manner shown by Cut 39, which shows the general positions of the hoisting rails with their transverse supports, as well as those of the pumping part of the shaft, as seen when looking down the shaft.

It also shows, at the corners, by dotted lines, the manner of cutting and double-shouldering of the shaft timber, so that they may abut more firmly *both* ways, for greater strength and stability, which provides *suitable rest as well as end and side abutments*, to resist both end pressure and tortion.

After all this work has been finished down to the water-level, the chips of wood should be carefully taken out of the water and sent to the surface, so that they may not chip the clack-valve, and destroy the proper action of the pump, when the water has been drained to the depth of the suction-holes.

All being now ready in the shaft, the pumping engine may be set to work in the manner described at page 379, not forgetting to bridle the opening of the top handle with a suitably long rope from above, so that the engine may be prevented from running out too fast. If the engine is so heavy in the house that the present attachments in the shaft are insufficient to bring her away, a pump (water-pipe) may be lowered on to the top of the shaft-catch, or attached securely

to any other part of the main pumping rod, and be filled with iron or other material, if necessary to do so, which may be again regulated at pleasure by throwing counteracting stones into the balance-box.

Provided the shaft-end has an excess of weight, and this top equilibrium valve is thus bridled, you will find little trouble in starting the engine, if you pay sufficient attention to the governor, steam, and exhaust valves' handles, and the balance-box may be used when you have leisure to watch the top handle for its separate regulation.

A practiced worker will require no such precautions at any time; for he will watch and control every movement with the greatest *nonchalance*, according to the requirements of each case, with surprising precision.

The engine should be worked in a steady manner, at nearly full speed, stopping for just a second between strokes, for the valves to close more easily than they would do if the engine worked at the full speed of ten or twelve strokes per minute, by quick or slow downward travel, as varied by more or less balance.

The engine is said to be "working off" when no stop is made between strokes.

Ten strokes per minute is a good working-off speed; seven and a half strokes are safe for pit-work, and economical for steam; whilst twelve are used but when urgent expediency are necessary. This variation of speed may be managed entirely by the balance-box, which governs the faster or slower downward travel of the pumping rod; whilst the speed of its elevation by expansive steam will be the same.

Thus, two seconds for ascending and three for descending will equal five seconds for each stroke, or twelve strokes per minute; and two and four will equal six for each, and ten of such per minute; and, again, two and six wlll equal eight for each, and seven and a half per minute. When safety is more to be desired than the very utmost economy and speed, it is better to occupy more time by using the steam at less expansion, as three and five, which also equals eight, for seven and a half strokes per minute.

The pump is now dropped as the water is extracted, until the working barrel and accommodation chain, or perforated

plate described, have descended as far as practicable, when another pipe can be put on the top of the pump, and the pump rod can be lengthened as described and necessary.

It will be found very convenient, in such cases, to keep a suitable clasp or nipper for the bucket rod, screwed or hinged to one of the pipe's bolt-holes, so that the two *tongs-like parts* may grip the rod when necessary, by being screwed transversely together by a bolt that passes through both parts at the other side of the pump's flange. They may be either passed aside on the swivel when not thus required, or may be allowed to serve as a central guide for the bucket rod, during its actual work of pumping.

Whilst these operations are being repeated, for ridding the shaft of water to its very bottom, the spare hands may assist the carpenter and timberman to complete the hoisting gear; its shaft derrick bearers for the large twelve feet pulley, which should have light wrought-iron arms; the four vertical and diagonal rails, and the pulleys that must work on a bar at the bottom of the perpendicular, to guide and transfer the wire rope, hemp rope, or chain, around the corner to the line of the inclined shaft.

If it is intended that the men will be some day elevated to the surface in these skips or cars, they should be attached to the rope on the safety principle, which is simply arranged by attaching the rope to a suitably strong transverse spring, to which is also attached appropriate catches, that will grip the rail very securely, when the strain is removed, which, in working, is its own weight; so that the breaking of the rope will occasion this instantaneous action for gripping the rail and arresting the car.

It is the more convenient mode to allow this car but to approach the bottom of the shaft, to be filled from the lowermost plat, or hand-tackle brace, as may be more convenient for lodging and re-filling the rock.

A strong "pentice" should be next fixed in sloping position just over the one end of the shaft, to screen the workmen from falling matters, which had better be bolted together in a more portable form, in one or more parts, with an iron eye near the top, for the lashing to pass into, during transferrence to lower positions, as the shaft is deepened.

By this time, the pump will be "*in fork*," which means that it *sucks air*, and should be attended by the shaftmen, to see that no chips enter the holes, and to drive previously prepared wood pins into the upper rows of holes, so that the water may be drained down to a lower level, which pinning is again repeated until the bottom row of holes alone remain open, and the water is sufficiently low for working purposes.

The "*lift of pumps*" should now be swayed into the best position for sinking, and properly stayed for greater facility and safety during the dropping of the pumps for sinking the shaft.

The ladders are also put into convenient but temporary places, down to within some twenty feet of the bottom; and an iron chain ladder is suspended from this to the bottom, for withstanding the rocks that will be hurled against it by the powder during blasting. The shaft may be put in general good order, in all really essential matters; but that little place called "Hull," sometimes frequented by the "*last core by night men*," must be dispensed with; for our favorite mottoes have been, and must still be, that—

Persistent expediency and consistent economy are the more surpassing powers that overcome the heavier recurring costs of wet mines, and which will lead the way to success oftener than all other means.

Commensurate wages for work performed: good men fairly paid; bad men not wanted.

Long contracts, from price in sight, and no advantage taken, neither from the past nor for the future.

Those who act otherwise rob both the employer and the employed, and many there are who do so continually.

In such mines, the miners' pantaloons are mostly worn at their seats, for all are endeavoring to "lay to" and dodge the captain, whilst he is making fair weather at head-quarters by referring to his *regularity of low wages.*

Shareholders should know that ground is most irregular, and that the best agents cannot keep the contractors' wages at certain amounts, if contracts are set in good faith for advantageous periods; so that if they study their own and the mine's interests, the agents should not be blamed for occasional high wages, thus obtained by a change of the rock.

The preliminary mechanical difficulties are thus got over, and we are now in a position to thoroughly develop the mine to its longest and deepest sections.

This is a time of great mental satisfaction to the supervisors, and the custom has been to make it jolly for the men, by giving them a substantial dinner; which is both first and last, so that no earthly reason can be assigned for the discontinuance of the hospitable and congenial practice.

I am not going to tantalize the reader by enumerating the viands of what Americans call a "square meal."

It has been stated that the profitable depth is supposed to commence, in our lode or vein, at or about three hundred feet under the adit or drainage level; so that our utmost endeavors must be directed downwards, to attain this desirable depth as soon as possible, by every means that is consistent both for speed and economy.

Now it is possible to sink the shaft to this depth by but two "drawing" or "suction" pumps, similar to the one now in the shaft, but with an improved bucket, which will be described in its proper place. These suction pumps may be then superseded by one or two "plunger" or "force" pumps, to hoist the water either the three hundred feet at once, or by one hundred and fifty feet twice.

To do this, it will be necessary that each draught pump shall exceed the depth of one hundred and fifty feet some fifteen feet, or be able to pump the water from one hundred and sixty-five feet deep, so that a fair chance may be given for fixing the cistern and castings for the pumps that are to follow and connect therewith, when the surplus pipes from the former are moved over on the latter pump; so that they may mutually elevate the water through their respective parts of the shaft. The ordinary bucket valve has seldom been used for more than ten, and never for the actual sinking of more than twenty fathoms through a gravelly shaft; and much difficulty prevails for even this.

At the North Pool Mine, Cornwall, we sunk by the improved bucket two shafts (the one nearly perpendicular, and the other inclining about 55° from the horizontal), for twenty-seven and a half fathoms, with the greatest ease, without the least sign of failure of the pump; and the

opinion was that fifty-two and a half fathoms might have been sunk by this one pump.

The action of this double concentric valve is much more steady than the single valve; for whilst the former are guided, the one by the other, perfectly straight through the barrel, the latter is most unsteady, for its leather receives every tremble from the rod, and wears at least four times as fast. This last feature was most remarkable; for, at the termination of the sink, the buckets were still serviceable, after three weeks' run. The upper bucket appears to receive the strain and do the heavier part of the work, whilst that at the bottom merely follows, and keeps more readily water-tight.

Having plenty of upper room, we used wood bucket rods (instead of iron), that were strapped together when necessary to lengthen them during sinking; and by keeping the head of the upper rod above the set-off from the main rod, the bucket rod was dropped, when required, in the easiest possible manner, by first screwing on yokes where it should stop, and then partially unscrewing its main attachment staples.

Wood rubbing pieces were placed over the heads and nuts where the bolts secured the rods together in the pipes.

The top end of the bucket prong's stem terminated with a flat iron "sword," which had some five or six holes, through which the bolts passed from the forked end of the wood rod, for strong connection thereto.

In such positions, I very much prefer wood to iron, for they are cheaper and more reliable, and can be applied with much less trouble; whilst they float instead of sink in water, and their extra size causes an almost continuous, instead of intermittent, stream from the "collar launder."

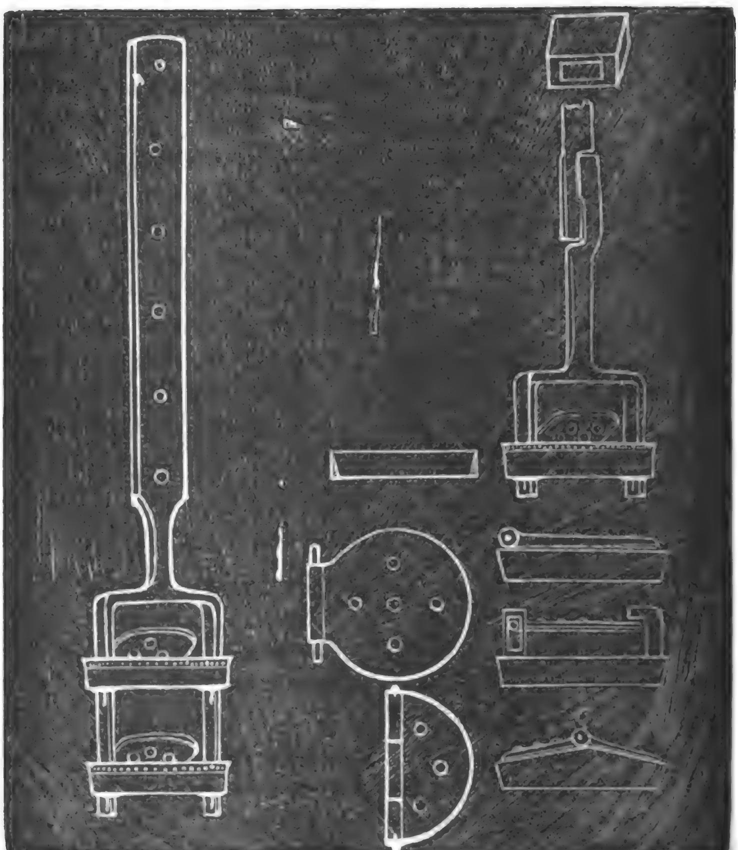
The accompanying illustration (Cut 40) shows, first, the improved double-valved buckets and prong; then the old bucket prong, its connecting clasp, and its single bucket, as well as both their stems, as connected to wood or iron rods.

These buckets are geared in an easy yet substantial manner, by two folds of leather, which are cut to the right shape by a pattern, and enclosed by the adjoining ring being driven up over them (as shown by Cut 40), firmly keyed from beneath, and thickly nailed around the margin by two or three rows of flat-headed gearing nails.

The leather should not stand more than an inch above the enclosing iron ring; and if the hoop is well fitted, three-fourths of an inch will be better.

Next under this is shown the ordinary plain clack valve, when closed; then the more favored *hinge-rising*, water-clearance clack, when open; and, lastly, the double wing "butterfly" clack, which is very useful for large pumps.

Cut 40.



Having decided on sinking the shaft by the improved double bucket to this depth of one hundred and sixty-five feet, your next duty is to obtain an efficient corps of shaft-men, which is by no means an easy matter, even in Cornwall; for this department requires not only much experience, but a

mixture of good common sense with superior and especial mechanical talent.

The skilled pilot, and trusty, weather-proof sailor, are not more valuable on the treacherous, foamy shore, than are such miners for engine shafts.

There is vastly more required here than the mere use of the pick and gad, and the drilling and blasting of holes, which may be learned in a comparatively short time.

The good shaftman is, amongst men, like the beaver amongst animals: intelligent, and somewhat amphibious; and it would be just as consistent to put rabbits in beaver-banks, as to put mountain miners in wet mines.

Here the superior Cornishman is at his play, and surpasses all others; he is therefore more necessarily required in this than in any other department of mining.

As a rule, the whole mine awaits the deepening of the shaft; and as so much depends upon it, the price of such skilled labor should not be estimated in a niggardly manner, nor too much contracted by the number of men and length of their working hours; for the cost of each foot or fathom is not governed by the simple amount of money the men will receive at the end of the month, but by this amount added to all of the necessary costs for working the machinery, agencies, etc., etc., with the loss that may be occasioned by such delay to the mine; and, consequently, it frequently happens that it is better for the mine to give much more than the ground is really worth, if it leads on the men to extra exertions for a greater number of feet during the month.

I have, under these conditions, set the contract in such a manner that the last numbers of feet should obtain a greater price than the first.

For example, if the least number sunk during a month would be ten feet, the price, up to ten, should be say $20 per foot; exceeding this, to eleven feet, the extra depth should be at $21; the next additional foot should be $23; the next, $26; and the next $30: so that the men should be thus encouraged to greater exertions than by any other means, and the mine be greatly advanced.

So, also, is it frequently advisable to have the men working

by four instead of three shifts, so that they may keep working all the time.

In some cases, two good men and one strong boy may compose each corps; at others, two good men, one ordinary man, and one strong boy may be better; but, in all cases, the two experienced men should be employed, for the one may be ill, or may not arrive to his duty, when consequent hindrances would occur.

There is in all cases a necessity for keeping two sledges or mallets on the drill; whilst the strong, lively boy may do many things better than men, as running errands, and filling the kibbles or buckets.

Your shaft, being thus manned and contracted for, should be sunk as speedily as possible, and every facility should be afforded the men for doing so.

Beyond the tools and materials that are required for drilling and blasting of tunnels and dry shafts, a small pump, a claying iron, and some one of the water-tight cartridges, will be required, as well as a little tallow, and some adhesive clay.

The suction pump may be made by fitting a suitable stick, wrapped with twine or rag, into an old gun-barrel, to suck the water out of *such holes* as can be fired without a cartridge, by putting a circular dam of clay around the mouth of the hole, to keep the water back.

The claying iron is made of wrought-iron, which is slightly tapered, for a length that equals your deepest holes, to suit the top of the hole loosely; above this, it must be squared and stamped like a sledge, which serves for both driving and withdrawal, after the hole in the rock is first filled with clay; by hammering it down therein, it fills the fissures around the hole, and keeps the water back, after the claying iron is withdrawn, by the insertion of a drill or other bar in its transverse hole.

For Regulating the Speed of the Engine—So that the water may be kept at the desired height in the bottom of the shaft during sinking, I have used a short pendulum, which, being suspended against the wall, near the engine driver, he can most readily know the exact speed that is required for all recurring purposes.

For example, we will suppose that the pendulum is six inches long, and that you take it in your hand and *hold it at the one end* of its stroke, so as to release it exactly at the moment the *engine commences* to make its stroke; when, by counting the number of vibrations *made by the pendulum*, during the time the engine *makes the stroke*, you will, by *recording it on a slate*, know, and *be able to bring the engine to*, exactly the same speed for future similar purposes, as governed, from time to time, by the shaftmen's knock, etc.

This is as readily made as it is easily used; it is remarkably effective and serviceable, for suiting the various requirements of the shaftmen; whilst its delicate action detects the slightest increase of water, during the deepening of the mine.

It will be unnecessary to minutely describe all of the various details of shaft-sinking; but, of course, such things as the different shifts of ground, as joints, favorable faces, clay seams, or soft streaks, must be closely watched by the men, for making better speed; and by the agents, for better estimation of the future price of the ground. Good powder, and reliable safety fuse (the double and triple-taped), strong water-tight cartridges, which may be made by the men at the time, from strong brown paper, folded over a suitable stick to suit the size of the hole, and greased to prevent the water from entering between the seams to the enclosed powder.*

These cartridges had much better be made by an especial hand, at the surface, of the several sizes, and be first pasted with flour, then dried, and supplied to the men when necessary, like all other materials; or they may be still better made of thin tin, contracted sufficiently at the neck, for the better wrapping of the fuse.

The extra cost of such is trifling, or perhaps nothing, when comprehensively considered, for the whole of the powder is

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* The present well known Bickford's safety fuse is but of comparatively recent invention; but many lives have been saved, and much more work performed, since its invention and introduction in Cornwall. Previous to this time, rushes, and quills (the one in the other) were filled with powder for this purpose; or a steel spike was rammed up with the tamping, and then withdrawn, so that the space it occupied might be filled with powder, to cause the explosion of the mass when ignited.

dry and undeteriorated; so that the utmost effect and certainty is secured, with less loss of time, limbs, or lives. But were it not thus so, it is contemptibly "narrow-gauged" economy to recklessly hazard the more numerous delays and accidents that would otherwise prevail.

It sometimes happens, in very hard shafts, that no such reliefs from joints, etc., as alluded to, can be taken advantage of, as the rock is homogeneous, and tremendously tough and hard; so much so, that even in Cornwall, with its cheap labor, £100 per fathom was but insufficient price for the ground, and very slow progress can be made.

In such cases, I imagine that the firing of a series of holes by the electric spark, at the same exact instant, would so assist each other, that an artificial crack might be thereby made, for the whole length of the shaft; whilst two or three holes might also assist each other, for portions thereof, and produce a much better collective result than any series of separately fired consecutive holes.

This has not yet been tried in hard shafts.

For such positions, any powder that may possess much greater strength will be invaluable to the miner.

The "Giant" powder is said to have this desideratum; it is certainly much more effective in open cuts, and in quarries; but I have not seen it used in mines. If it has no objectionable property, such as more obnoxious gases, it must be very extensively used for general mining purposes. Its strength is so much greater, that smaller holes have to be drilled for its reception, which brings into use the single-hand drilling hammer, instead of the double-hand sledge; which is, in itself, an advantage, more particularly to a new country, as one man drills, instead of two, who requires less air for breathing, less materials, and lastly, but not least, less instruction and practice, for becoming an expert hand.

The greatest care should be taken in tamping holes, as accidents are by far too frequent.

The powder should be first gently rammed down with a ramming *stick;* then add the tamping, little and little, which should contain no flinty matter that would strike fire; using a copper bolt rammer first, then finishing by iron, if necessary to do so.

It is probable that these premature explosions arise from one of two causes; first, by the striking of sparks of fire by the iron tamping bar from the tamping, or the sides of the hole; and, secondly, by compression of air, either in the interstices of the powder, or under the *excessive quantity* of tamping, which hardens to fill the hole *at the top*, whilst the underlying air is so suddenly compressed by the blow, that its *latent heat* becomes sufficiently *sensible* to ignite the powder.

We will suppose that the shaft had been, in this meantime, continued in the manner described to the depth of one hundred and fifty feet, where either a permanent plunger pump must be fixed, or another temporary bucket pump; so that, in either case, ground must be excavated for the cistern, which can be done cheaper by carrying the whole down to the proper level together, in similar position in the shaft, and in similar manner to that for the house plunger pump above; when, after the shaft is sunk to one hundred and sixty-five feet, the cistern may be placed therein.

In this case, it shall be a plunger pump.

The angle beam must be now fixed in its working position, at half-stroke; the main rod connected therewith from above, then continued down the shaft to within a safe distance of the bottom, and stayed similar to that in the upper part of the shaft.

Rollers must be now fixed to support and carry the rod through the stroke, which should be straight across, and be about two feet in diameter, and an inch wider than the rod. The thin wearing pieces, of some strong, hard wood, may be secured to the rod by staples or nails.

Three angle-turners are shown by Cut 41. The first, or the bell-crank, is the best; but hard ground sometimes compels you to substitute the double railway of the second; or the third, which I devised and applied very successfully at the North Pool Mine, Cornwall.

It will be seen that this performs the work by *one railway* much better, for the *angle* is also divided into halves.

The top of the pole-stock is tapered to a wedge, which conforms to the vibration of the rod, and works admirably.

The flat-bottomed suction pipe for this permanent force pump can be next lowered into the cistern, and the H piece

be placed thereon, and jointed in the usual manner, by the aid of thin wrought-iron rings, that are lapped by ribbons of common coarse flannel, that have been dipped in a diluted mixture of coal tar; upon this the upper clack-box is again jointed, and the pole-case, with its stuffing box, is also screwed on over the other end of the **H** piece; the wood-stocked pole is then placed in the pole-case, and lined to true working position under the main rod, as for the house plunger; and a parallel filler made to go between the rod and pole's stock. The whole is then securely stayed sideways, and shored up under, so that it may keep in correct line to its work, when it is ready for receiving its valves, the packing of the stuffing box, and for being closed up for work. after the column of pipes has been reared to discharge into the drainage level cistern.

The force pump pole should be attached to the main rod by its permanent staples, and tried for pumping properly in line, etc., before the column of pipes from the draught pump are transferred over from that pump to this; and a working barrel, of the same size as that of the shaft pump, should be attached to the flange of the upper clack, to serve for a draught pump, if the valves of the force pump should be disabled, and the water arise above these doors.

A transverse bar may be also inserted across the joint, so that a drop clack may be used as before described for the drawing lift; and thus the pump will be doubly secured against irrecoverable loss.

An air-cock will be also found very useful in the pole-case, as by opening it during the down-stroke, and shutting it during the up-stroke, the air is thereby so much expelled that the pump obtains its water with much promptness, even at times when, by leaky valves, it would altogether fail to do so without it.

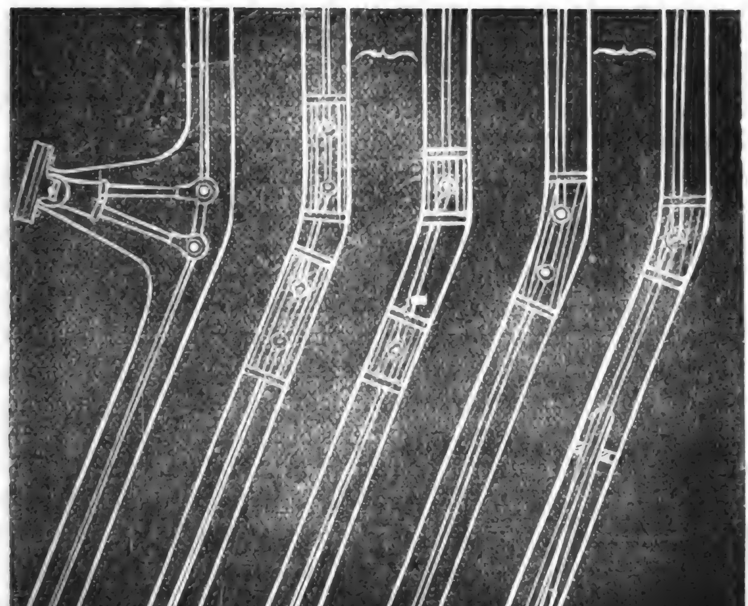
The bucket and rod must be hoisted out from the shaft pump, and its upper pipes transferred over to form the column to the plunger pump; whilst the new and lowered head of the shaft pump may have its leather or canvas bag transferred to, and secured for discharging the bottom water into, the the new pole's cistern, whilst the latter discharges its water into the house lift's cistern.

The same set-off being lowered and attached to the rod at suitable height above the head of the bottom pump, it is again ready for pumping.

If another bucket lift had been applied instead of this plunger, it should have been fixed where the plunger is, in similar manner to the other, excepting that the set-off, and its connections for working, would have been on the other side of the rod.

The shaft must be now sunk as fast as possible to the three hundred feet level; and, to do so, the drawing lift will but repeat what has been described, to attain the same depth of one hundred and sixty-five feet, for the fixing another pole at

Cut 41.



the three hundred feet level, where the quantity of water will be more accurately known, and the size of the pole may be regulated accordingly. So, also, can this pole elevate the water the whole distance of three hundred feet, when necessary to do so, after the shaft has been sunk deeper, and the levels have been extended away for larger and safer water spaces, by the transferrence of the upper pipes to the lower plunger pump's column. If this three hundred feet pole is applied, it will be better to have the lower pumps made

thicker, so as to gradually increase from those of the upper half, as the pressure becomes more.

Being to the desired depth where mineral can be reasonably expected, the two levels must be driven away at the height for tip plates, with all speed, to explore the ground; and if you are satisfied with your mine, as demonstrated by the shaft, as soon as the levels are clear from the shaft, it must be again sunk in the same manner and for the same depth as before, of one hundred and sixty-five feet for the one hundred and fifty feet level.

The railroad cars may be next brought down to this level, for being filled from the tip plats; whilst the shaftmen are protected, as before, by the pentice. Their rock is now to be hoisted by hand-tackle, until the skip may be more advantageously brought deeper. The sinking of the shaft should never be stopped until you are convinced that the mine is too poor in depth for further exploration or profitable development.

THE LIGHTING OF MINES, MILLS, ETC.—Has had less attention given towards its improvement than any other department of mining; for, although coal gas was first invented, and introduced into Cornwall immediately after its invention, for the illumination of towns, it has been but recently used in the lighting of but one large mine; and, being found too expensive for such a comparatively trifling purpose, it was abandoned in favor of the contemptible candle.

The first cost of works, and the subsequent recurring running costs, of coal gas, are far too much for such purposes, and prohibit its use.

Fortunately for the poor miner, who has been too long groping his way in "darkness made visible" by the flickering candle, there is now at hand, in Rand's valuable patented invention and applications for producing illuminating gas, the very boon and desideratum for his purpose. I have been employed by this, the Pacific Pneumatic Gas Company, in various examinations relating to its general characteristics and chemical properties, and have seen numerous testimonials from others who have used it in mills, public institutions, and in dwelling houses; and am pleased to be in a

position to recommend it to my fellow mining men, for all the places above and below the surface of mines, etc., where from ten to one hundred lights are required for the illumination of *fixed positions*, such as ladder-ways, tram-ways, plats, levels, pump fixtures, winzes, etc. Of course, the candle may be used in the sinking of shafts, or excavation of the ends and stopes, as before, if preferred. This gas is somewhat heavier than air, and can be used in the deepest mines without trouble.

It commends itself to your notice for the following reasons.

1. The first cost is but from $200 to $350 for a ten light, and from $500 to $1000 for a one hundred light machine, dependent on position, etc.

2. The gas is produced by merely forcing common air through gasoline, as performed by a kind of clock weight arrangement, which is wound up by a *few minutes' work* of one man, just when the gas is required, and but *once per day afterwards;* so that no *fires or retorts*, or other running expenses, are incurred.

3. The light is even superior to coal gas.

4. The products of combustion are of a more pleasant smell, and less injurious, than the average of coal gas.

5. The cost of running is but one cent each light per hour.

6. The gasoline is so light and cheap for long carriage.

7. The whole apparatus is so simple, safe, and efficient, that it cannot well get out of order, when in operation.

8. In mining for gold and silver, it produces no grease to interfere with amalgamation.

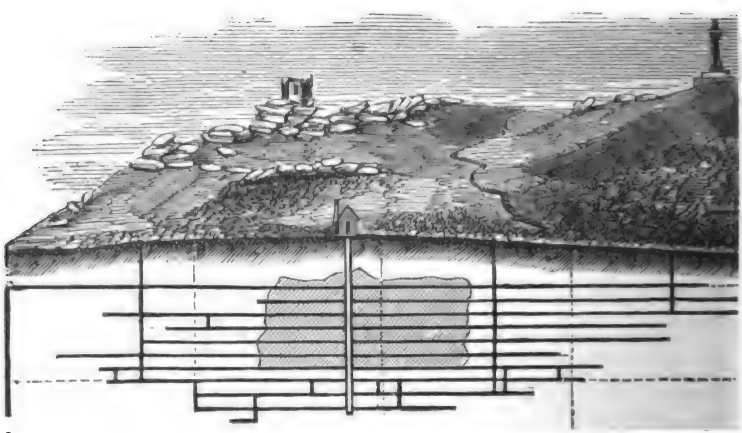
As these levels are extended from the shaft, the price of ground, indications, and value of the lode, should be closely noted in a book, and on a section of the workings that should be kept for that especial purpose; the former recording full general particulars, whilst the latter shows to the full view of the agents and stockholders the plain or secretly figured prices of ground, value per fathom or foot, dip of ore, and degree of congeniality: so that in the future realization of its value, these facts shall not be forgotten, but serve to facilitate the profitable extraction of the mineral.

To work deposits of ore for greatest advantage and economy, as governed by distance from the shaft and the surface, ventilation, dip, etc., requires much study and calculation;

and the reader is referred back to Cuts 4, 5, 6, and 7, Section I, at pages 89, 90, 91, 92, 93, and 94, to give him some of the more important ideas as to the very important matters of too frequent levels, remote distances of the deposits from the main shaft, dip, advance of oblique intersections, etc.; and to Cut 42, from an actual section, for too many levels through hard and poor ground, and improperly placed winzes, as there palpably exposed.

There is a great necessity for an efficient portable power, for superseding the manual labor that has been thus far used for hoisting the rock, and sometimes the water also, from the bottoms of shafts and winzes, which we now require in the sinking of our shaft under the present railway's terminus; so that the rock may be hoisted, not only from the greatest depth of man's present winze

Cut 42.



tackle power (about one hundred feet), but to that of our one hundred and sixty-five feet; or under a greater necessity, as for proving the bottom of a distant wing, as at the left bottom level wing of Cut 42, or sinking of winzes in advance, even to three hundred feet from distant level to level; so that where ore is found remote from shafts, local levels may be driven from such winzes through the ore ground only, as conveniently as from a surface shaft, when the ore may be trammed back to the main shaft, for elevation to the surface. The quantity of money that has been expended in driving ten-fathom levels, for want of such a power, is enormous, even in cheap labor countries.

I have devised a machine for this purpose, that answers every requirement, even that of safety for hoisting over men's heads (as I am fully aware of their just dislike to steam hoisting from such places); but, as I have just taken steps for securing patent rights, it will be injudicious to explain its construction at present.

The actual section of an abandoned mine, as illustrated by Cut 42, will serve to show where the workers were desirous of proving an interesting part of the left wing of the mine deeper; but, having no greater power than the hand windlass or "tackle," they could but sink some ten fathoms; and similar cases are continually occurring in mining, where such greater facility would be immensely valuable.

As soon as the shaft is four hundred and fifty feet deep, two other levels must be driven in a similar manner to the three hundred feet levels; and when a sufficient amount of ore has been discovered, one or more shafts ("winzes") must be sunk from level to level, for convenience of working the ore, and for better ventilation; these "winzes" should be regular, neither too close to the shaft, nor to each other (as in Cut 42), or money will be wasted; for, as an approximate rule, it costs thrice as much for excavating shafts, and twice as much for levels, as it does for stoping the lode.

Should you require increased ventilation for the engine shaft, or for driving the levels before the winzes are through, the shaft may be much improved by the close timbering of the division between the engine and whim shafts, so that an ascending current may traverse the one, whilst, in the other, the colder air is allowed to descend; the level may be easily ventilated by attaching a long inverted cistern to the main pumping rod of the engine, to work in another somewhat larger cistern, that must be nearly filled with water, and in the middle of which a small central pipe, that passes up through its bottom and the water, for the admission of the air, as the upper and inner box is elevated by the engine; an air-tight valve is placed over the top end of this small inhaling pipe, and the air is then exhaled through another suitable valve and pipe, into the one or more levels, as the engine rod descends.

In removing the ore from the vein, natural columns should

be allowed to remain as safe supporting margins on both sides of the engine shaft; and the principal winzes and large excavations should have occasional arches left standing, as nothing is so safe for sustaining the ground as these natural supports. The poor rock should be also filled into the vein's space, where practicable, as it saves hoisting, timber, etc., and is stronger and more enduring than timber.

The ends should be driven of ample height and breadth, for obtaining suitable room, ventilation, and tramming facilities; the full cars should have a slight descending grade, and, as previously stated, tip into the shaft plats.

In stoping the vein, several modes are practised; but those that can be wrought above the level are more convenient and economical, and are thus executed—

1. *Directly overhead, from movable stages*, when the stuff falls into the level, for conveyance to the shaft, and to the surface by the railways.

2. *From the winzes, horizontally forward*, as suitable steps of the vein favor, when the stuff is brought to the winze and dumped directly into and through a mill (or contracted way) into the car or level below.

3. *Stoping and driving the ends forward*, by the same party of men, may be often advantageous, when not hurried for returns; for the bottom of the level being properly squared and graded, the top expense for squaring may merge into that for stoping, by forcing the bottom forward only when required.

4. *Under-stoping is only resorted to for forcing the mine's produce beyond its legitimate yield*, to help the costs for deeper development, or previous to abandonment of what is deemed worthless.

However the ground may be stoped, great care and judgment must be brought to bear in securing the vacated ground, either by natural pillars or arches, by replacing the worthless rock, or by suitable timber.

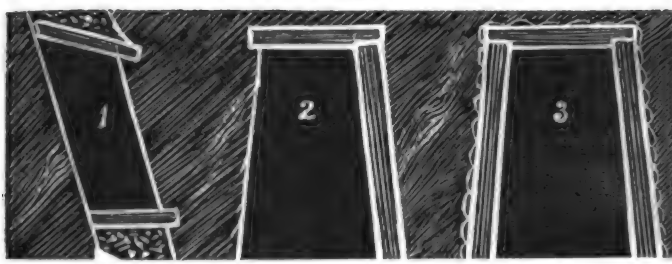
The above depths between levels are intended for the improved machine; but, otherwise, from sixty to seventy-five, or at most one hundred feet, must be adopted, for reasons stated at the end of this chapter.

THE METHODS OF TIMBERING SHAFTS, LEVELS, AND STOPES— Vary so much, according to circumstances, that little can be said that will serve for general adoption; but the following hints may be of some service.

If it be required to form a safe horizontal footing bearer (as Figure 1, Cut 43), care must be taken that the hanging-wall end shall be sufficiently recessed in firm rock for certain support, that it jams endways, and has a tightening taper on the foot-wall.

If head timbers are required for supporting the fillings of poor rock and the ground, similar precautions must be taken; but, as a much greater weight has to be withstood, the angle against the opposing wall should be still greater than before, as shown at the top of the space (Figure 1).

Cut 43.



If the one side of the level has firm ground, whilst its head and the other side has treacherous ground, it may be sustained after the manner of Figure 2, by a single upright, head-piece, and side-shore.

And so where the whole surroundings require being supported, as in Figure 3, which explains itself.

These are the modes for timbering under ordinary circumstances, which are modified to suit individual cases; but sometimes, in stoping very large and rich veins, a net-work of bracing timbers may be more advantageously used, which connect with each other by a kind of horizontal and vertical frame-work, somewhat similar to the beams and posts of a three-decked war vessel.

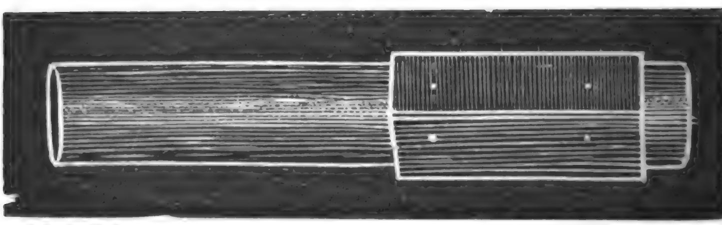
So, too, in sinking very soft shafts, and driving levels through decomposed or decomposing ground, which will run together if not immediately secured, the side-planks are so

arranged that they may be sprung and driven behind and in advance of the last frame, until another frame can be placed to support their innermost ends.

For cutting and shouldering the timbers to the necessary square and bevel, I have introduced to workmen the accompanying square and bevel, which are great comforts in use; for, no matter how much the timbers may be rounded at the corners, this instrument will, by hugging the two sides, mark the transverse line much more easily and correctly than any ordinary square or bevel can possibly do.

It is made two feet long on each edge, by nailing two pieces of straight plank together at right-angles to each other, squared at the one end for shaft timbers, and bevelled at the other end for level timbers, and which may be divided as a common rule; holes may be also drilled at suitable distances

Cut 44.



back from the end, to mark where the shoulders are to be cut. It is shown at Cut 44, as laid over a round stick, which it will also saddle, and mark as correctly, for square or bevel shoulderings.

Double and Single Hand Drilling.—It will not be out of place in this part of our work to say something of the two systems of drilling, as practised in different districts of Cornwall. The double-hand method is generally adopted throughout Cornwall; but, in the western extremity of the county, the men of what is termed the St. Just District almost invariably drill single-handed.

An eastern man generally insists that the double-handed mallet is better than the single-handed hammer, whilst the western man as stubbornly favors the single-hand hammer. The former requires two men, the one to hold and turn the drill, whilst the other uses the mallet or sledge; the latter,

one man turns the drill in the one hand, and hammers it with the other, and by practice is enabled to change the works from the one hand to the other at pleasure.

As an eastern man, I have had opportunities of closely watching both modes, and would express my opinion with as little prejudice as possible.

The manager who has not learned the value of both these methods for certain places, under appropriate conditions, wastes money in breaking ground; for whilst the mallet and sledge, with large holes, are incomparably valuable for the more speedy sinking of wet shafts *under the blow*, the hammer, with smaller holes, is equally valuable for the driving of levels, working of stopes, and rising or sinking of dry winzes, more particularly in small lodes, embedded in moderately hard ground, which need not be hurried at the expense of economy. It frequently happens, too, in the same end or level, that once in a while the larger drill may be advantageous; or, where the larger prevails, the smaller may be used occasionally. So in shafts the "jumper" is good for both.

In looking at the mere matter of drilling, you should not forget other comparative advantages, which are occasionally, as stated, somewhat governed by the necessity for expediency.

The double-hand system requires—

1. Ample room for two men to use the longer drill, and more clumsy, long-handled sledge or mallet.
2. These holes therefore cannot be drilled so diagonally for better advantage in blasting.
3. Air for two men.
4. Wages for two men.
5. More stuff broken and hoisted, for the larger way.
6. Deep holes have more comparative resistance to overcome, for the quantity of rock broken by the same power.

The single-hand system requires—

1. Room but for one man.
2. The holes can be drilled by either hand, just where, and as obliquely, as he desires.
3. Air for one man.
4. Wages for one man.

5. Much less tools, materials, and timber.

6. Less stuff to be broken and hoisted, which, in stoping small veins, is very much less, for they can work sideways into very narrow space.

7. Small, shallow holes have less resistance to overcome in blasting than deeper and larger, so that the same powder breaks more rock.

8. It is much more easily learned, which is, in itself, a great advantage in new countries.

In driving and stoping, or sinking or rising dry winzes, in moderately hard ground, I am fully satisfied that, generally speaking, this single-hand has an advantage of some twenty per cent. over that of the double-handed system; whilst, for stoping and following small veins, it is still more economical, as no side country rock need be broken.

In fact, no double-handed tool is used (not even a pick); for in the one hand they hold the picker, or variously shaped steel drills, wedges, and chisels, which are struck by the other hand with a short-handled hammer; so that all these much lighter tools may be carried on their persons, to work into the otherwise inaccessible places.

In fact, where a full-sized man can barely enter, they can work, in *a sideling manner*, with comparative ease; and such places are thus made to yield profits, that would not do so, if side ground had to be broken to make room for *fronting the work*, by the double-hand mode.

Subterranean Pumping Beams—Are sometimes required for pumping water from parallel veins, through cross-cuts, or to prove the bottom of a distant wing of the same vein, when an ordinary right-angled "bell-crank" lever is attached to the main rod, and the gudgeon fixed at the top of the level, so that the "queen post" may, by hanging, *draw the water during the up-stroke* of the engine.

Surface beams should draw by a "queen post," in the same manner, wherever practicable; as this motion, being quicker, draws the water much better, and does not interfere with the balance, for proper speed during downward travel.

Subterranean Balance Beams.—As the shaft is deep-

ened, the main pumping rod should be slightly reduced in size, under each succeeding plunger; and on attaining a depth of say one thousand feet, a strong balance beam should be fixed, so as to relieve the upper rod's strain at its surface connection, just under the rod of the surface balance box, which may be thus partially discharged of its cargo, as the underground box is being filled. Another balance beam may be fixed at the two thousand feet level, for similar reasons.

In very hard ground shafts, an especial plunger-pole may be attached, which should have sufficient area and height of water-column for balancing. Of course, no valves are required for this purpose.

It will be thus seen that the rod and its connections are too heavy even for forcing the water by plunger poles to the surface, and would be much worse by having to elevate both the rod and the water, by draught pumps, during the up-stroke.

This single reason is all-sufficient for demanding the use of the Cornish pumping engine, which really does the work in descending, by this properly balanced rod.

As this chapter has already extended over more pages than I anticipated, and as deeper developments will *but repeat operations*, it will be unnecessary to go into further practical details of working operations; but, before closing, I may say that the depths between the levels are just suited for pit-work mechanisms, and the new hoisting machine suggested is intended to make it also agreeable to both; but, without it, hand power compels you to keep to, at most, one hundred feet levels, both for pumping and hoisting purposes, and although the men work too hard, all operations are cramped. The almost universal practice of Cornwall has been but ten fathoms between levels, although, in some modern instances, twelve fathom distances have been adopted, by forcing men's muscles thus much further.

In ore ground sections, *remote from shaft, or otherwise, intermediate levels may be extended from the machine winze through the ore ground, for purposes of stoping the vein, at any convenient distance;* but the cost for driving through long distances of barren ground should be saved at all times and places.

CHAPTER VI.

THE CORNISH CRUSHING, STAMPING, FLUMING, JIGGING, BUDDLING, FRAMING, AND ROASTING MACHINES.

THE CRUSHING MACHINE.—This machine is made but after the one most approved pattern, and erected in the following manner.

A strong house is built, of about twenty feet square, which is fitted with bottom and top floors; the latter lies on the strong beams which carry the crushing gear.

Into the one end passes the driving shaft, that is worked by water or a steam engine, such as will be described under the next heading, for stamping; this shaft, which passes through the house on the upper floor, carries a large pocketed vertical wheel, just inside the first wall, for elevating the coarse ore that may require crushing the second time.

In the middle of the house, and on this shaft, a thick cast-iron roller, of about two feet long, and from two to three feet in diameter, is firmly keyed; and just opposite to this, another similar roller is placed, which is keyed on an especial axle, that also extends to the second wall, where they gear by equal tooth-wheels, so that the crushing rollers shall revolve at equal speeds towards each other on top.

Now the second crushing roll is kept to contact with the first by two transverse levers, that pass out through the side wall, and which are weighted at pleasure, to suit the hardness of the ore, by suspended winze-buckets, as more or less supplied with scrap iron. Short right-angled lugs, on and under the inner end of these weighted levers, abut on suitable saddles, which force the crushing-roll brasses inwards, as guided by their suitably arranged slides.

Now, if the engine is started, and the rolls are supplied with rock, it will be crushed between, and pass down through

these rolls; whilst the levers, having proper freedom, will ease off from rock of dangerous hardness, or from an accidental piece of iron, to prevent breakage.

On falling through these rolls, it passes into a revolving circular sieve, which is sloped in a manner to sift what is sufficiently fine into a wagon, or on the floor; whilst the coarse is passed into the vertical wheel (called "raff wheel"), for elevation and repetition of the process, until it will pass through.

The rolls are also *supplied with rock* by appropriate mechanisms, that work an inclined railway car.

It will be seen that everything is provided for in this crusher; that friction is as little as possible; whilst more rock can be passed through in the same time than by any other yet devised.

THE CORNISH STAMPING ENGINE.—This engine is in all respects similar to the pumping engine, excepting that it has a crank and fly wheel, and lacks the consequently unnecessary "cataract," or intermittent *resting* time-keeper.

They almost invariably receive steam but the one way (on top of the piston), which works to from one-fourth to one-tenth expansion; whilst, during the ascending half-stroke, it is equalized both over and under, for its mere warmth.

The beam works on the wall, half in and half out, and the connecting rod is made extra heavy, for balance, during the up-stroke of the piston, which is further regulated by a balance-box on the outer end of the beam itself, so that it may be still more accurately balanced, for the difference of work.

THE CORNISH STAMPS (OR BATTERY)—Should be, economically speaking, driven by water-power, or by the vertical, long stroke, high pressure, single expansive steam condensing, Cornish engine, as described, in a direct manner, by coupling-box connection from the engine axle to that of the stamps, so as to run round for round, instead of using the unnecessary tooth-wheel connection. (Belts have never been used for this purpose in Cornwall, and should be most certainly discarded, as being expensive and unnecessary.)

Such engines, which have been demonstrated after long

trials, beyond possibility of mistake, to be the most economical and serviceable engines for fixed purposes in the world, have been too often supplanted by the horizontal double "condenser," or the "puffer." These engines accomplish maximum economy when revolving about twelve rounds per minute; so that the thus driven and driving barrel (which is precisely on the principle of an organ or musical box barrel), by having five "cams" or tappets to the round, elevates the "heads" or pestles sixty times per minute. These suitably perforated cylindrical cast-iron or solid wood axles (in which the elevating tappets are wedged securely) drive a maximum number of sixteen pestles, into four mortars; or twelve in three mortars; or eight in two; or four (or sometimes three) in one; and by adding and coupling on more such axles to the first and to each other, the pestles may be increased from sixteen to thirty-two, to forty-eight, to sixty-four, to eighty, to ninety-six, to one hundred and twelve, to one hundred and twenty-eight, etc. (Five pestles in the one mortar are never used in Cornwall.)

Although these large round axles and two and a half inch square lifters are generally made by one piece of iron, they may be in several, and are as often made of wood, at the mine, even in Cornwall, when the small working axle of wrought-iron is securely fastened into each end of the former; and the stems of the pestles, which are cast into the iron, or sometimes wedged, are inserted into the bottom iron-bound ends of the six-inch square hard-wood lifting stems.

When made entirely of iron, it is heavier; but when these parts are made of wood, at the mine, it is lighter than those of California.

The "lifters" or stems, and the pestles, are not round as those of America; but the former are made of from two and a half to three inch wrought-iron, or from five to six inch hard-wood; and the latter of white-hard cast-iron, in oblong shaped chills, both horizontally and vertically, varying in size from ten to twelve inches by from six to seven in the bottom, and from one foot to two feet three inches in height.

Thus, it will be seen that although they do not turn round, they fill the mortar, cover the rock, and discharge the pulp, much more effectually than the round pestle; and the

wrought-iron shanks can be again used, without wastage for new pestles. If any irregularity should be perceived in their wear, which has not been found deleterious, the pestle and lifter can be turned, occasionally, half round.

These pestles may be either used on the (strongly bolted) *wooden*, or *natural*, bottom; or on corresponding cast-iron bed-plates, made especially for the purpose.

The pulverized ore is generally forced out from the mortar through perforated plates; but sometimes it merely runs up an inclined flume, in waves, until it becomes sufficiently fine to pass over, as suspended in the agitated waters.

It therefore appears that the two theoretical and primary apparent advantages of twist and lightness are more than counterbalanced from greater subsequent economy of fuel, wear and tear from higher speed, friction, the unnecessary leather belts, and by the practically more efficient crushing and discharging facilities, as obtained by the square, mortar-filling, direct-acting tappet system.

THE FLUMING TROUGH—Is used for separating ores of a certain size, which are already sufficiently small for market or other treatment, from those that are too large; which latter are at the same time washed clean, for hand separation on suitable tables, by boys or girls; as also for separating the heavy, which lies at and near the head, from the lighter and less valuable parts, which pass away in the water towards, or entirely clear of, the end of the race of water.

It is generally made as a simple launder, of wood sides and bottom, with an interior perforated iron false bottom, some four inches above the wood bottom. The iron bottom is nearly or quite flat, so as to retain the dirty ores, for being stirred and washed clean; whilst the wood bottom of the launder carries the debris away in the quick traveling water, for subsequent retention by cross-bars.

THE JIGGING MACHINE—Is used for the separation of the heavy ores from the light gangue, by water treatment. It operates on ores that have been first crushed to the size of split peas, which, being placed in sieves of suitable fineness, the water is caused to rise and fall through the ores, which

oscillation causes the lighter pieces to arise to the surface over the heavy ore, for being removed from the sieve by hand scrapers. It is worked in four ways.

1. By hand sieves, which have handles, for being well shaken by vertical reciprocating motion, and by horizontal twist, which works more effectually than any other.

2. By oblong larger sieves, that are suspended to an equal-ended lever, which works on an axle that is fixed on two columns, at some three or four feet from the water-troughs. This lever is worked by another lever, that is centered on the same columns, some twelve inches above the first lever, to return over the first, for being worked by a boy who stands in front of the water-trough and oblong sieve.

The attachment from the one lever to the other is not of *good fit*, but made by a vertical screw, which, by passing from the furthest end of the first or lower lever up through a hole in the upper lever, in a loose manner, can be regulated by nuts over and under the upper lever, in such a way that the proper sudden shake may be given to the ore and water. On being shaken sufficiently, the working lever is passed down to the ground, and secured by a rope loop, or a catch, and the lighter surface debris of waste is then scraped to one side and cast away.

3. A row of such are placed side by side, and worked by a machine, from suitable cranks.

4. A series of round hand sieves are placed in suitable holes, on a long wood box or pipe, and these being partially filled with the ore, the water is forced up and down through the sieves, by the quick motions of one plunger pump, which is arranged to be worked into their common water-box, by suitable mechanisms, which vary the speed for the purpose. The sieves are skimmed off or removed as often as necessary, so that the waste may be passed away, and the concentrated ore transferred to its pile; when the process is again repeated as before. Double sets of sieves may be used, to save time in filling and scraping.

THE BUDDLING MACHINES—Are all used for the separation of the lighter gangue from the heavy mineral, which, being first agitated into mechanical suspension in running water,

settles subseqnently at certain distances down an inclined plane, according to specific gravity.

The ore for such treatment is first pulverized in stamps, to pass through a sieve of from forty to sixty meshes to the inch, and then beneficiated by one or more of the following modes.

1. Long, plain, gradually descending flumes, or box launders, in front of the battery, which, when full, are shovelled into separate heaps, of different qualities, according to their distances from the head of the stream of water which carries the almost impalpable ore from the battery.

2. The common oblong hand buddle may be easily understood, and made from the following description.

A pit is excavated in the ground, just below the level of the orey stream or dressing floor, sufficiently large for receiving an oblong coverless wood box, of some ten feet long by three feet wide, and two feet six inches deep. At the head of this trough, a wood slope is fixed, of a length equalling the full breadth of the trough, and about eight inches wide. Above this, a transverse launder conveys the water to this and other buddles, for washing the ore, which is sometimes supplied in a partially solidified, cakey state, and is then shovelled into a suitable head trough, or on a board, for the purpose, as often as necessary, by a boy or girl; then disintegrated and distributed over the sloping head-board, by a long-handled rake, for the action of the water thereon. This water is thus made to enter over the ore by several diverging channels, between suitable strips of wood.

The powdered ore passes down into the box, and settles on an incline, according to comparative weights, close to, or more or less distant from, the head; whilst the water passes out through the end (which is perforated for that purpose), with the lightest gangue.

This graded incline of ore is occasionally smoothed by a suitable brush, ribbon, or rake, to keep it from being grooved by the water; and when the trough is full, the foot is shovelled into one pile, and the head into another, for future treatment.

3. The trunking buddle is arranged for the performance, by mechanical motion, of what has been done by the last, or

common buddle, by hand. A series of properly sloped flumes are embedded side by side, which have transverse divisions at their heads, for separate water-boxes, into which the water flows over the cakes of slime that require disintegration and concentration. Over these water-boxes, which are situated at the head of the buddles, an axle is supported, which, running from end to end, serves for the attachment of as many shovels as there are buddles, which are so secured by their hilts to this axle that they shall descend into the water of the head boxes. These shovels are kept in slow but continuous motion, as worked by a rod from some reciprocating power, which is applied to a lever that is keyed on one end of this axle.

The thus agitated waters wash and keep the ores in suspension, which pass over the several flumes, launders, or "trunks," to settle in relative positions as under the hand-buddle described; and one good boy can attend to the whole series.

4. The original, round Brunton's buddle, as supplied from the centre with the water that brings the mineral in suspension, to be distributed over the convex disk, and smoothed from channeling by revolving brushes or ribbons, taking all things into consideration, is the easiest made, most speedy and effective in operation, least liable to derangement, and cheapest, of the several circular buddles that have been since devised by others, for the effectual separation and concentration of *all of the several heavy auriferous minerals*, if not for the complete separation of the *one single mineral*, the oxide of tin.

I understand them as being very different operations; for whilst, in the former, you have to retain all the heavy ore in as hasty a manner as possible, in the latter you have to accomplish complete separation of the one oxide of tin from all, or nearly all, of the other heavy minerals; some of which approach closely to being of the same specific gravity.

This buddle may be made in the following cheap and easy manner. Sink a circular pit in the ground, of suitable depth and diameter, which may be made to vary from three to six feet deep, and from twelve to twenty feet in diameter, according to the requirements of your case. Floor the whole pit with wood three inches thick, and build thereon, first, a wood,

brick, or stone wall round its periphery, just inside the cliff of ground, which must be perforated with holes; and then a central hollow cylinder, of wood, stone, or brick, for receiving the axle and supporting the supply flumes for the ore, which is suspended in, and brought by, the water, either straight from the battery flumes, or from especial stirring troughs, when treating older solidified slimes.

Into the central hollow cylinder a vertical axle is introduced (which works into a stool at the bottom, and on a cross beam at the top), on which is placed one or more transverse arms, for carrying the brushes or ribbons, which are intended for moving the accumulating pulp across the radiating stream of orey water, so as to prevent the accumulation of lumps and the formation of water channels, and distribute the thin sheet of water and ore all over the convexed slope.

These arms that carry the brushes should be attached to a socket, which should be so balanced by two weighted chains that work over pulleys, that the sweepers may rise as the pit fills with ore.

This being done, the arms may be properly balanced, and started to revolve at from three to six revolutions per minute.

The water that carries the ore may be now turned into the annular trough around this central axis, which, being provided with several outlets, affords free passage for the water and ore to run out through, and down over, the outside of the cylindrical centre of masonry, to commence concentrating the ore in superior quality at and near to the centre; whilst the inferior and worthless gangue is passed away at the circumference, through suitable holes, in the manner described, until the pit becomes full.

Two or more machines should be arranged in a row, to be driven by the same shaft and power, so that when the one is full, the stream of mineralized water may be shut off from this and passed over the others, whilst the one or more are being cleaned up. Previous to clearing a pit, a circular line of demarkation should be drawn just where the quality is sufficiently high for beneficiation, when that inside may be saved, and the outside passed away, or put aside for a repetition of the process by another buddle, situated further down the stream.

It will be sometimes better to increase the diameter of the inner cylindrical stone wall, so that the entrance line for the mineralized water may, by being extended in width, increase the supply of the ore and speed of its concentration.

Several machines may follow, for closer concentration.

I think that this ordinary buddle, thus modified to suit circumstances, taking small first cost, with great simplicity and efficiency, into account, will answer better for the concentration from the auriferous debris of *all the heavy* particles, *which gold* only *requires*, than those more modern and refined mechanisms which have been especially devised for the more *complete separation* of tin oxide, *both from the heavy and light debris.*

A machine that is best adapted for the one may not be so efficiently arranged for the other.

The American concentrators are at hand, and are sufficiently put forward by the inventors and others to expose their comparative merits with this, as well as with each other.

THE MACHINE AND HAND CONCENTRATING "HINGED FRAMES."—These somewhat ancient hinged frames are probably the most exacting and perfect concentrators yet devised by ancient or modern mechanisms; for where a comparatively complete separation is wanted, such as for tin oxide, they beneficiate the wastes from all other machines; more particularly those that are denominated "hand frames," which are directed with the superior intelligence, and worked by the power, of educated girls or boys.

THE HAND CONCENTRATING FRAME—Is simply an oblong frame of wood, about seven feet long and four feet wide, which is made to border a flat table, somewhat similar in shape to a billiard table. This table is made to slope from about seven to ten degrees from the horizontal; it is hinged across its middle, in the direction of the running water, so that it may be turned in a vertical position as often as a sufficient amount of tin or other mineral accumulates thereon, for washing it into suitably placed troughs below, for further separation of qualities; whilst the worthless gangue passes away in the water over its tail-end.

A sloped head-board is arranged, similar to the hand buddle; but it is wider, to suit the greater breadth of the frame, and a leather-hinged wood flap, that runs this whole breadth, overlaps the frame when it is in the act of concentration, and rises to accommodate its turning to vertical position when it is being washed free from the concentrated ore.

It is worked by a hand-rake or hoe, in a similar manner to the hand buddle, until the time arrives for washing, when, the supplying stream being first turned off, the frame is thrust to the vertical, where it is washed clean by a long-handled horn or scoop, and returned to its proper position for repetition of the process.

The action is much more perfect than the buddle, for no more than about one-sixteenth of an inch thick accumulates at any time, as it is then washed off into the receiving troughs.

THE MACHINE CONCENTRATING FRAME—Is made in a similar manner to the foregoing hand frame, excepting that the axle is fixed somewhat on the one side of the centre of the table, and *brought to balance* by a piece of iron, *when free from ore.*

Several machines are placed in a row, and the agitated water carries the ore over the different frames, each having levers, which are connected together by a long rod, so that as soon as a certain amount of the concentrated ore has accumulated on the larger halves of the tables, its excess over that on the other halves causes them to upset.

Instead of being hand-washed as before, **V** launders are fixed just over the top edges of the tables, which being capsized by the motions of the latter, this water washes down the ore from the face of the table into the underlying troughs; whilst a balance-box at the end of the whole arrangement is regulated to gradually fill with water, for the purpose of returning the tables for another operation, *ad infinitum.*

The whole run is generally attended by one boy or girl; but sometimes a girl stands between every two frames, to combine the advantages of both the superior work of the hand with the greater ease and speed of the machine.

THE CORNISH ROASTING FURNACES.

THE HAND FURNACE—Is generally made of a mixture of both common and fire bricks.

A large square floor or bottom is covered over by a very flat dome, which is more or less secured by exterior iron bolts. One or more fire-places are built at the one side, and the chimney at the other; whilst on the other quarter, or quarters, apertures are left for the occasional stirring of the ore with hand-rakes. The roof should be as low as possible; and when opportunity affords the advantage of a hill-side, a covered flue may save the expense of a mason-work chimney. Receptacles should be also built or excavated for arresting and settling the volatilized elements of sulphur, arsenic, etc., so that they may be sold as such in the market.

THE HORIZONTALLY REVOLVING MACHINE FURNACE—Which is called the "Calciner," is the most thoroughly efficient of all roasting apparatuses, for it may be made to volatilize at any desired temperature, during any length of time; whilst the pulverized ore is being stirred continually, from the time of its entrance until discharged, by the most effectual self-acting motions. This furnace is made and worked in the following manner.

A low wall is built, in a circle of from eight to twelve feet internal diameter, and some five feet in height, that receives the horizontal cast-iron table, which is attached to, and supported on, an axle that is provided with a wheel near its lower end, in which a "worm" gears for producing a slow, regulated motion, as turned by more or less water passed over a small wheel, kept for the express purpose. Excepting this small sub-opening to, and the "crow" for, this worm-wheel and axle, and the openings for the reception of the roasted ore, and one or more ash-pits and fire-places, the interior of the bottom of the round-house is built up solid, to within some six or eight inches of the revolving table, leaving but just room in the centre for the axle to work.

Just on line with the upper horizontal surface of the table, one large, or two or three smaller, fire-places may be built on the one side, and a chimney on the other side, for the creation of draught and conveyance of the heated gases away,

which have been volatilized from the ore during the passage of heat from the fires.

The pulverized ore, and salt when necessary for silver, is supplied by a central funnel-shaped pipe, which passes through the flat, arched, circular top of the furnace, that is strongly built of fire-brick, which may be partially supported by suitably shaped iron beams. Under this roof one or more radial series of flat stirrers are placed, so that they may be turned on their axles, and adjusted from without, in the manner to *stir* and pass the ore, *at any desired speed*, from the centre outwards during the process, for simply roasting off the sulphur, etc., or for simultaneous chlorination.

Several of these machines may be worked through the same chimney, and by one man, as, after they are once set going, it is only necessary to feed them with ore and fuel occasionally.

In starting these furnaces into effectual operation, it will be necessary to first warm them up to a low red heat, by the fires, before adding the pulverized ore, when the latter, having been added, should be examined on its exit, to see if the passage through was too much hastened or retarded; so that it may be regulated from the exterior top, by turning the stirring rudders more for the one or for the other, as required. This being once adjusted, the fires should be regularly supplied with fuel, and accurately regulated by the dampers, to obtain perfect volatilization by sufficient temperature, without the conglomeration that is so often produced by other furnaces, from excess of heat and lack of motion.

See the illustration of this roasting machine, in Chapter I, Section V, on "Roasting," etc.

CHAPTER VII.

DRY AND WET CONCENTRATION OF ORES, BY HAND, WATER, ACIDS, AND CALCINATION.

The base minerals and the precious metals may be concentrated in numerous ways; but the following are some of the most efficient methods that are resorted to by the miners of the older countries.

DRY CONCENTRATION BY HAND—Has been, and should always be, resorted to, as the most advantageous and effective preliminary means for separation of different qualities of rock into piles, for direct sale of the best, and subsequent more economical beneficiation of the remainder, by the other more general methods of concentration, after pulverization.

1. *The miner should commence this method by casting the paying streak of rock into one pile, for separate conveyance to the surface;* for, when in the hand or shovel, it may be passed almost as easily into two heaps; and thereby not only the time is saved for subsequent especial surface separation, but the wastage from its greater crumbling to small particles, that can be again obtained but by expensive means.

2. *The rock should be dumped from the car*, over two or three diagonally placed, iron-barred screens, so that the different sized rock may, by falling from the one of these screens to the other, be sized to fall according to the different distances of these bars from each other, in each succeeding screen or sieve; the finest will thus fall through the finest screen, *which may be jigged by water;* the medium size will fall through the middle screen, *and after being washed clean in a flume, may be separated by being hand-picked on tables, by girls or boys;* the coarse stones will pass through the third, *for further assortment by hand-picking, and direct passage through crusher or stamps;*

whilst the rocks will pass beyond all, *for being broken with a sledge to proper sizes for mill or crusher, and separation of qualities into several heaps.*

CONCENTRATION BY WATER—Is generally performed after pulverization to almost an impalpable powder, of nearly equal state of fineness, either by the buddle, or frame, described in Chapter VI of this Section; or by the German shaking table, or one of the Californian concentrators.

The "pump jigging machine" has also been recently applied for concentrating finely pulverized ore, by using fine sieves, and one hundred and fifty short, half-inch, strokes per minute. The impoverished debris passes from the one sieve to the other in a series of such sieves; so that hand-scraping is unnecessary, as the light passes away, whilst the heavy settles down through into the sieves and troughs.

It is a well established fact that no machine or hand concentrator can be made to extract all of the heavy from the lighter powder, in one operation; nor will any one of them concentrate in a manner that is both sufficiently economical and complete for either marketable purity, or for chlorination, *without causing an escaping loss over the tail-race of water;* so that it is generally advisable to first work by more than one concentration, and then to arrest the heavier escaping debris in large pits, where it settles to the bottom, in the slow-traveling water, for more subsequent beneficiation.

The hand and machine frames described in the preceding chapter are the most exacting concentrators of Cornwall, as the hand-rocker is in California; yet, in spite of even them, the tailings from mines may be worked over, by other cheap labor, again and again, for further profitable extraction; which is probably caused from *difference of the shapes and sizes of the pulverized ore*, which cannot be so well avoided.

This is such a natural consequence, that family after family manage to obtain a living by re-treating the slimes, as they pass away by slow-traveling rivers, some several miles into the sea, from some of the best worked tin-dressing floors and largest mines in Cornwall, and from each other.

It is therefore most essential that the battery should be above a convenient declivity, for the necessary repetitions of

first treatment, as well as for suitable catch-pits, for subsequent beneficiation of that which would otherwise escape.

The several flumes in front of the mortars of the battery may be sloped like hand buddles, and be arranged in pairs, so that every alternate one may have the water diverted into the other, whilst it is being cleaned up, similar to the hand buddle, according to quality. The partially concentrated head may be conveyed to one set of round buddles, or machine frames, whilst that at the tail may be treated by another set; and the still escaping poor slimes may be caught in pits, for beneficiation by contract, at certain percentage of value, as known by assay, actual chlorination, or other reduction.

THE SEPARATION OF TIN OXIDE FROM TUNGSTATE OF IRON, BY HYDRO-CHLORIC ACID.—The oxide of tin is first roasted, and re-washed on frames, for ridding it from sulphur, arsenic, and the other forms of iron; when the tungstate of iron is removed by humid treatment, with hydro-chloric acid, which must be added to proportion with the quantity of the wolfram (or tungstate of iron) that is present.

This acid treatment is imperative, because, from too similar specific gravity, the wolfram cannot be water-washed off; and being non-volatile, fire also fails to release it.

CONCENTRATION AND SEPARATION BY CALCINATION.—Many minerals which are associated with volatile elements may be calcined to great advantage, for the direct removal of the objectionable portion by fire; and sometimes the remaining element is so changed thereby, as the sulphuret of iron when it has been oxidized, that it becomes friable, and may be passed away by a repetition of water treatment.

The oxide of tin may be taken as an example, which, being frequently associated with the sulphuret or arseniuret of iron, cannot be entirely passed away in water; but roasting volatilizes the sulphur and arsenic from the iron, which then becomes oxidized, so that it may be wholly separated by being again washed on frames, when the iron can be so disintegrated that it is then suspended and floated away in the highly reddened water.

The treatment of other minerals will be given in Chapter I, Section V, on Metallurgy, on the general results of roasting.

CHAPTER VIII.

PREPARING AND SAMPLING THE ORES FOR THE MARKET.

The base minerals are generally sold by the miner in their raw state, for reduction by especial metallurgical companies; and are prepared into heaps, and sampled, after the following methods.

1. *Tin oxide*, after being concentrated on frames, as described in the preceding chapter, is roasted, when necessary for removal of the objectionable sulphur and arsenic, and the thus oxidized iron is passed away as stated, by framing the roasted ore. A finishing process is then resorted to, called "keeving," where the ore is placed in a large tub or "keeve," covered with water, and struck on the outside by a wooden mallet that is suspended in position and worked either by hand or machine motion.

This operation serves to arrange the particles to settle according to their specific gravities, in a more accurate manner, and frees any soluble matter that may have adhered to their surfaces during roasting.

It is an imperative necessity that the oxide of tin should be brought to a state of thorough concentration and purity, or the smelters will not give anything like fair value for percentage of tin. It is then dried and sent to market in sacks, where it is ticketed for by each buyer, in sealed envelopes.

2. *Lead sulphuret* (*galena*), should be concentrated very closely; but not, from necessity, to such state of purity as tin ore. This is generally done by hand-picking, jigging at split-pea size, and by the peculiar modern jigging, buddling, trunking, or framing of the unavoidably fine ore.

The closely concentrated ores are weighed in barrows, and conveyed to the floors to compose equal piles, which are inti-

mately mixed and of the shape of an inverted prospecting or frying pan; according to quality.

These piles are supposed to be of equal quantity and quality; but when the samplers for the different smelting companies arrive, they have the privilege of selecting either one of a number of a supposed quality and quantity, for their assay and total weights.

This pile is then cut through the centre (as shown at page 120), and a quantity is taken therefrom and mixed on a large iron sampling plate, quartered, and the opposite two quarters cast away; the remainder is mixed, and the operation repeated until a little more than the actual quantity that is required for the samples is retained. This is then pulverized and passed through a fine sieve, when each sampler fills his small bag for assay.

The other qualities and quantities are then sampled for percentage of assay value, and total weight, by the selection of any one pile from the number, in the same manner.

After these assays are made, the several agents from the smelters' companies are supposed to bid their best fair price for the ore.

3. *Carbonate of lead* is mostly separated from the gangue *by hand;* and as it is not difficult to smelt, and will not stand water treatment so well, it is never so closely concentrated for the market as galena.

In subsequent respects, it is, after being thoroughly mixed in piles, sampled and sold in similar manner to galena.

4. *Copper ores* may have many grades of quality, from three or four to eighty-eight per cent., as the smelters of this ore are able to reduce it within any of these proportions by appropriate mixtures the one with another, etc.

All may be jigged, buddled, trunked, or framed, for concentration; excepting the *red and black oxides, which water carries away.* The latter must be therefore separated from the matrix by hand-picking.

The samples are taken, in the manner described for lead, and the ores are purchased from the assays, at regular meetings of the smelters' agents, that are held in the towns for the purpose, when the highest ticket obtains the ore.

The value of copper ores may be estimated by multiplying the standard of the day by the percentage "*produce*" from assay; then dividing this by 100, and deducting the nominal customary returning charges of £2.10*s* per ton.

Lead may be estimated in similar manner. The returning charges bring £6.10*s*; the value of the silver it contains may be added thereto.

The ore is then carried from the mine to the port, by the buyers, for shipment, but weighed at the expense of the mine, in the presence of the sampler for that particular company of smelters.

5. *Antimony, iron, manganese, zinc, etc.*, may be concentrated by hand or water, to from fifty to eighty per cent. of mineral, and be piled, sampled, assayed, and weighed, as the preceding.

The ores are weighed in a very expeditious manner in Cornwall, in *balanced* hand-barrows, which are filled from the pile by one or two men, and carried by two others to the scales, which has the one end provided with a curved iron rest, so that the double-handled barrow may be readily placed thereon, or withdrawn, as necessary.

The captain takes charge of the scales, and books the number of barrows against the smelter's agent, who sees that each barrow turns the scales to fair quantity, which is regulated by another man, who shovels the ore in or out from the barrow, as required for balancing each barrow. Seven barrows, of three hundred and thirty-six pounds, with an addition for the previously ascertained water-weight, makes the ton; or any other quantity may be taken to suit the various ores, and the peculiar customs of other districts.

CHAPTER IX.

CONTRACTS; SETTING, PAYING, AND ACCOUNT DAYS.

CONTRACTS.—Mining requires an efficient and equitable system of contracts, more than any other business; for it has so many attendant, recurring, sustaining expenses, to keep the ways open for excavations; and the workmen are so distributed, and necessarily hid from observation by the ground itself, that they cannot be kept at work, on mere daily or monthly wages, by any means within reach of economy; and therefore nothing but their comparative constitutional honor and industry can be relied on for accomplishing the proper amount of work.

For some men, these are all-sufficient; whilst for others (and they are in strong majority), contracts must be resorted to.

It is just as difficult to change the naturally industrious man into lazy retarding habits, as it is to encourage the more indifferent into industrious practices; so that nothing short of actual contracts can realize justice for good men, or fair amount of work for wages given to constitutional schemers.

1. Contracts, to be of any value, should be really founded on the merits, and completed according to the real facts, of each case; irrespective of how much, or how little, ground may be broken during the terms of the agreement.

2. The words of contracts should clearly and minutely express the terms of mutual agreement.

3. The real hardness, etc., of ground, as in sight, should be the guide for the price, at per foot or fathom, *no matter how much or how little has been driven during the preceding contract;* for nothing is more calculated for lessening the amount of honest labor, than those perniciously elastic "give-and-take" and "best-upon-trust" systems, so much used by agents, who are afraid that their employers will blame them

for the occasionally high wages, which *must* sometimes occur, if such contracts are made in a fair and unalterably decided manner.

4. *Monthly or certain long-distance contracts* should be made; and that miserable system of "two fathoms *or* the month" should be forever excluded from setting-books.

It is but a "make-up" convenience for the agents to regulate prices at the men's expense, who, being thus defrauded of wages so honestly won by change of ground and hard work, become disgusted; and what bears the name of contract is but mere burlesque, and is worse than monthly pay.

5. Stockholders should select good agents, and never blame them for such unavoidable figures, for they but rob themselves by such conduct.

Setting Days.—In the Cornish mines, the measurements are made for the past month, and the contracts for the sinking of the shafts, driving levels, and stoping the ground, are let at the end of the working month, on the "paying day" for the work performed during the month that precedes this; so that one month's pay is thus kept in hand, to serve as security for faithful performance of engagements, and to afford the clerk an opportunity for posting his accounts during the interval, from measurements and general particulars obtained from the agents.

These setting days for the future, and paying days for the past works, are generally on Saturday, but sometimes on Friday, as governed by the first, second, third, or fourth Saturday or Friday in the month; so that the third time of paying becomes five weeks.

To prevent unnecessary extravagance or retention of materials, they are supplied to the different contractors at a price somewhat above their real cost or value, and the quantities used are to be deducted from their total amounts, as derived from ground broken under contract. So the smith's cost, serves to prevent willful blunting of drills; as whim-drawing charges, compel them to fill their kibbles and work in a more judicious manner.

To provide funds against accident to limb or life, for the workman or his survivors, each mine in Cornwall has a club,

into which every man is compelled to pay one shilling per month, which is also deducted; for this sum, he obtains the services of a doctor, or the family his coffin, and some £10 for burial expenses, and assistance at the burial.

It will be quite an advantage to the miners of this country to have a similar institution in the permanent mines; as, by paying say $1 per month, they may be provided with assistance in living necessity, and have their last rites duly and respectably performed.

Paying Days—Are arranged for the afternoon of the same day as that for the measurement for past, and letting of future contracts, so that no unnecessary waste of time may result therefrom.

Each contractor is provided with a full statement of account for ground broken, and deductions made under contract; and at the time each man (boy or girl) is paid, the clerk or purser marks on the cost book this fact, opposite the respective names, for future reference, until all are paid.

The small merchants' bills, carriers, whim-drawers, etc., are lastly paid in similar manner.

It has been the invariable practice, during the past, to have a dinner provided for these occasions, at the cost of the proprietors; which is still held to be good for both the mine's and agent's interest, as well as for visitors who may be there on pleasure or business.

This dinner is cooked and spread by the "account-house woman," who should be an expert in the substantial matters of this auspicious day, and be generally useful during every lesser day of the month, for things in general; but, more particularly, for washing the "captains'" characteristic canvas coat of snow-like whiteness, which are customary annual perquisites from the company, for which they are proudly grateful.

These dinners were originally introduced as a means for both entertainment and technical discussion, for elimination of useful information and errors in connection with the working of the mine; but it is seldom turned to this account in modern times, as the after-dinner discussions are swerved for toasting the local or visiting worthies that smile on the superior punch as made and supplied by their presiding manager.

Account Days—Are similar, but larger and more select meetings, of the agents and stockholders, which are held in copper mines, at two, four, and six months apart; and in tin mines quarterly or half-yearly, as governed by the periods of the sales of copper or tin.

At these meetings, all practical and financial matters are discussed, and what shall be done for the future is determined; and either money is provided by "call" or assessment, or dividends are declared, as the audited accounts and state of the mine may warrant.

The site of the "account-house" or office should be such that the windows shall command a full view of the surface laborers, who will, so far as they know, be thus continually overlooked by the agents.

The most convenient and economical way for providing a suitable office is to combine the carpenter's, pitman's, and smith's shop, as well as the store-house and iron-yard, therewith, in one run of buildings.

The smith's shop will be better built at the one end; its roof should be supported by occasional pieces on the walls, so that the vitiated air may have free traverse from within to without, for better ventilation.

The iron-yard should be next; then the pit and timbermen's house, the upper floor of which may be used as a store-room, which should have the general entrance, as well as a door from the office.

Then the other, or last end ground floor, may be used for carpenter's shop, which should also have a saw-pit in the middle, to run its entire length, and a small hole in the end-wall, for passing long timbers, during the sawing.

The office conveniences may be on the long upper floor of this part of the building.

A small house should be built on some remote and safe site, for powder magazine.

CHAPTER X.

THE MOST IMPORTANT AND MORE FREQUENTLY RECURRING ERRORS IN MINING, WHICH MAY BE MORE EASILY AVOIDED THAN COMMITTED.

It has been the practice of navigators to record and chart the latitude and longitude of dangerous shoals and rocks, unusual currents of water, the peculiar periodical constancy of winds, and the variations of the magnetic needle, for the better guidance of future voyagers over this world's waters; for it is a comparatively easy matter to warn all from what they, as individuals, have seen, and thereby teach others to avoid such treacherous ground.

It is just as easy for the miner who has observed, during a life, many shoals and rocks of error, to erect a few beacons, so that future miners may not run recklessly to ruin, for want of knowledge of such as should be carefully avoided.

The following observations are recorded with an intention to do good to this young mining country, in the easiest possible manner, and are given for the consideration of those who do not already know, and for the guidance of such who may wish to avoid the too frequent errors of the past.

THE MOST IMPORTANT AND MORE FREQUENTLY RECURRING ERRORS WHICH HAVE BEEN COMMITTED IN THE MINING OF OLD COUNTRIES.

1. *Driving level after level at an unreasonably shallow depth, where minerals cannot be reasonably expected.*

A close examination of this subject will show that more money has been foolishly expended in this connection than in any other manner.

After the adit or drainage level has been driven, for the purposes of exploration and drainage, no other level should

be extended until you really get your shaft deeper than where the *other mines* of the district have produced mineral; for you have less water to contend with in sinking, do not waste money in driving through poor shallow ground, but keep it for the more substantial trial of the vein at proper depth; where, if you should find that the mineral rises higher, so much the better, for you have it in the best possible position for working, as well as a reserve for the regulation of returns.

2. *Too many levels have been very often driven through unmineralized ground.*

Where ground is not known to be mineralized, it is folly to drive *every level* for exploration of distant wings; so, also, when a distant wing is known to contain a run of ore ground, *occasional levels* should be only driven for drainage and ventilation, when more frequent levels for convenience in working the ore may be driven from the central winze that has to be sunk for commanding such shoots of mineral.

3. *The bad practice of driving ten-fathom levels has been almost universal, even in hard ground.*

When it is known that every level must have its railway and "tip-plat," ventilation facilities, timber, cistern and cistern-plat, pump appliances, etc., with the consequent delays for driving the levels and of sinking the shaft, it must be admitted that the less frequently they occur, the better it will be for the economical working of mines.

Now fifteen fathoms may be sunk by hand windlass power, and one hundred and fifty, or even three hundred feet, by a suitable air or water machine, as alluded to in the preceding chapter.

The compressed air reservoir for the working of this engine may be placed at the surface, and be filled by any machine; or may be underground, and supplied from a pump that can be worked from the main pumping rod. It will have the advantage of providing ventilation by its discharge of air during work.

The water machine could be supplied with its pressure of water from the pump's column, as stated in the chapter on "Deep Mining."

4. *Shafts in improper positions.*

Such errors are frequent, and where allowed to continue uncorrected by other accurately placed shafts, great losses have resulted from mines which should have given profits.

Immediately this error becomes known, it should be corrected; for each day of delay increases its heavy penalty.

5. *Unnecessary vertical shafts.*

Well arranged vertical shafts are beneficial; but they have been often used under circumstances where they were *unnecessary, and positively injurious*, for the speedy and economical development of mines; more particularly such veins as were embedded in hard rock. The ancient *advantage for kibbles has passed away before the modern shaft railway*, which applies almost as well on the incline as the vertical.

The disadvantages of the vertical shaft are serious, for *much more speed of exploration can be made by the diagonal shaft on the vein itself*, than by the vertical shaft through the country. The *diagonal* vein can be sunk on *much faster; the lode's indications, and actual value are seen daily; and not only all corners and cross-cuts are saved, but straight-forward tramming* of the rock from *all the levels and stopes* is obtained.

It is therefore evident that vertical shafts should generally take the lode at about where the mineral becomes profitable in the vein, when the vertical part is required for proper attachment to the pumping engine; but for dry mining, when not required for this, it had better follow the vein in direct line from the surface.

The exceptions will be, where a *deep new shaft* is required for *increased facilities for pumping the water, and hoisting the mineral from a well ascertained large quantity*, where the country rock is sufficiently soft; or in coal mines, when the proof of the seam is deeper or of horizontal attainment, and very large quantities of coals have to be hoisted on one or more movable loaded cars.

6. *Mining in districts which are notorious for poverty.*

It has been an often repeated folly to expend much money in working mines that are quite outside of mineral belts and basins, and which are surrounded by worthless mines.

7. *Mining too closely to immense deposits.*

Many immense mineral prizes have been discovered in different parts of the world, and in almost every instance as much or more money has been wasted immediately around them than the great mines ever produced of profits.

As all of the mineral cannot be deposited in one place, a sufficient space should be supposed to intervene between it and the next deposition.

8. *Too little deep cross-cutting for side lodes, in the systems of "true fissure veins," before the abandonment of main workings.*

Many instances have occurred where immense riches have been missed for want of a trifling outlay for this purpose, when veins were even supposed to lie unexplored.

9. *The re-working of very deep and extensive old mines, which have given immense profits in former working.*

It is grievous to notice how much has been expended for this purpose, during the last twenty years, in Cornwall, by distant shareholders, who have been badly advised.

In the name of Fortune, what could they expect to realize? For, in the first place, they knew, or ought to have known, that the mine was poor when abandoned; secondly, that the cost for pumping out the water, preparing for hoisting, and extending the shafts and levels to discover and lay open new profitable ground, would equal the full value of a first-class mining prize; thirdly, that the chances were very much against them; and, fourthly, that immense bunches seldom lie in very close proximity.

10. *Faithless tenor of contracts; such as one, or one and a half, or two fathoms; or the month.*

Which means, in the first place, that at the price given per fathom, if the men should drive more than the distance (of say one fathom) during the month—which they should under ordinary circumstances do—the agent has the power to put his own price on the remaining distance driven, so as to modify the total figures.

Contracts should give unrestricted show to the men for at least one month's duration, whether it is for or against the mine, if you would hasten development.

11. *Want of proper accommodation for men.*

In wet mines, every facility should be afforded the men for drying their clothes, for wet clothes endanger their healths, and make them dissatisfied, so that neither fair labor is performed, nor good men retained on the mine.

There is but one kind of drying apparatus that is economical for the mine, and efficient or safe for the men, which is simply a small and *uncovered* steam boiler, which is provided with a safety valve, to give a slight pressure and prevent the escape of any vapor, as created by a fire that is too small for generating sufficient steam to escape at the valve. The fire requires very little attendance, and the exterior of the boiler will never become sufficiently hot to burn the clothes.

12. *Inferior hoisting machines, with chains and kibbles, or buckets, instead of iron or hemp rope, and shaft railways.*

A large majority of the Cornish hoisting engines are those with four valves (two for steam, and two for exhaust), which do not cut off the steam at a part, *for expansion*, but carry it the whole stroke; and therefore there is neither economy from expansion of steam, nor from the lessening of friction by the use of the superior shaft railway and rope.

13. *Unnecessary repetition of machinery.*

The first pumping engine is often too small for the economical pumping of water, so that another has to follow as depth is attained, and sometimes a third; with these extra expenses for machinery and delays, a good mine has frequently been made unprofitable.

14. *Deficiency of an underground hoisting machine power.*

Manual power for hoisting of water and rock is most inadequate for the requirements of the miner; as, for the reasons given in the chapter on "Deep Mining," it bridles expediency in general operations, and exhausts the men.

15. *The evils of climbing ladders, and lack of man-engines.*

There has been far too little attention paid to the elevation of men from deep mines by mechanical power, from either want of consideration, or a kind of bravado of agents, who can, of course, climb the ladders easily enough, because it is

the only exercise they get to keep them healthy. The poor miner has, however, to economize sufficient strength to enable him to reach the surface, after he has performed his laborious task of eight hours' work; and, consequently, the *amount of work done* has to be very much less than it could be if he were sure of being hoisted to the surface, after its performance, by machine power.

16. *Insufficient working capital.*

Where insufficient capital is known to exist, the merchants charge more for the extra risk, the agents cannot buy at the cheapest market, the men do less work, and the worst men only can be obtained; which, coupled with insufficient appliances, cramp all economical operations of market and mine.

17. *Injudicious purchases.*

All materials should be supplied by contract, and not be purchased from price-lists, irrespective of fair value.

18. *Merchant and store-keeping shareholders.*

The economical development should not be deranged because a merchant has contrived to become a shareholder, whether his shares be many or but few, as the other innocent holders are robbed in proportion to their interests, whilst the mine suffers to the full extent.

19. *Purser's percentage from merchants.*

This injurious practice should be deprecated; for, no matter how bad the goods may be, nor how much the practical manager may deplore the fact, the financial wires will overturn the best public purposes, for private gains.

20. *Captains' white coats.*

It is a most ridiculous practice to put white jackets on agents; for immediately they heave in sight, they become the "observed of all observers," and thus afford the very ready and more certain means for "skulking."

21. *Deficiency of effective underground agents.*

In large mines, underground agents should be appointed for each shift, so as to really stay below, for more closely

watching the operations and changes of both "tut-work" (contracts on ground), and "tribute" (percentage of value).

22. *The account-house, or office, too far away, or quite out of sight from the operations.*

The windows of the agents' house should command as much of the operations as possible, for it naturally keeps the operators more steadily at work, as they are fully aware that you can see them, when they cannot see you.

THE MOST IMPORTANT ERRORS OF AMERICAN MINERS.

In addition to some of the mistakes made by Old Country miners, the people of this country have run into errors of an entirely novel character. Mining has been to some extent over-acted there; whilst here, premature milling and smelting have created many an unnecessary failure, and consequent dislike, from such people, for even legitimate mining.

The following may be held up for continual remembrance, so as to lessen future losses.

1. *Mining in the market.*

This is more destructive than all other follies, for it lowers this substantial business for the worst purposes; builds "castles in the air," at the expense of legitimate mining; for no honest citizen can readily know the one from the other, until he finds his cash is buried in the foul catacombs of such mines. Thus bitten, he becomes vindictive, and his future life is devoted to one continual howl against mining, when the miner had nothing to do with him or his losses.

2. *Milling and smelting prematurely.*

Mills are often introduced by market miners to blind the stockholders and the outside public, from whom they would have still more victims.

In this country, however, the more straightforward miners have in very many instances sent forward mills in ridiculous haste, before they knew, or even endeavored to know, if the vein existed, or continued, for quantity or quality of mineral.

In fact, the rule has been to erect them as *assaying*, not *reduction* works.

3. *Far too little, of mining.*

In all mineralized veins, the quality and quantity varies very materially in different sections thereof, so that shafts and levels should be sunk and driven for the exposition of the vein; for it cannot be expected to expose its best in the chance surface croppings. So, too, when found mineralized in profitable quantity just where you are, it should be further explored, to ascertain its extent, before mills or smelting works are obtained or erected for its reduction; or the costs of such unnecessary means will be entirely wasted.

You cannot lose by waiting, under any circumstances; and in case of success, ample reserves will greatly favor the realization from the mine.

4. *Too much transverse shallow tunnelling through bed-rock.*

Veins should be always tested, as much as possible, by driving thereon, as each foot is then proven. It is generally much easier to sink or drive on the vein than transversely through the rock. There are but few instances where cross-tunnels can be made to prove or work veins cheaper or better than might have been accomplished upon their course; unless it is done to obtain greater depth, or to deliver rock to a better or more convenient dressing or reduction site.

5. *Ill-contrived pumping engines.*

There is no pumping engine that can approach to the Cornish, either for efficiency, durability, or economy; and therefore the rotary engines should be discarded for all heavy or deep pumping works.

6. *Single, unbalanced rope, hoisting engines.*

This single hoisting is palpably wasteful of power and fuel; for, in lowering the car by the brake, all the retarding force is wasted; as it might, by *double* or *balanced* draught, be economized for hoisting the ascending car, either in the same, or in another shaft. The load of the engine being also lessened thereby, a greater economy is realized from a superior degree of expansion.

7. *Concealing of regular statements of the working operations, and the financial expenditure, from the public.*

In the working of mining properties, it is highly desirable

and (if legitimacy is heeded) it is also beneficial to publish periodical statements and reports for the observation of the shareholders, as well as the public, who may become such, if afforded fair show; as they can then measure the merits of the one property with the other, and buy from their own judgment.

This would lead to the benefit of legitimate mining, by avoidance of the unworthy, and foster an increasing desire for such interesting enterprise.

8. *Too much reliance on scientific attainments, and an unaccountable disregard for practical ability and experience.*

The practical man may be relied on, and strengthened by sufficient science; whilst the mere scientist should be avoided in this peculiarly practical business.

9. *High price of all kinds of labor.*

I would express my views on this subject, for the good of my friends, the miners, who will doubtless see the plausibility of my reasonings.

There are many duties in the surface department of mining that can and should be performed by cheap labor of some kind, such as boys, etc., etc.

There are many veins in California which cannot be profitably reduced by high-priced labor; but if the surface duties, for dressing, tramming, milling, etc., were lessened, they could be worked at a profit; and, if so, more work would be thereby created for the higher-priced skilled miner.

Take the cheap surface labor from Cornwall, all its mines would be stopped, and the very occupation of miner be but in name.

Replace its cheap labor, the mines would be re-worked, and the miner benefited.

The same principle applies here, and hundreds of veins now unwrought can be thus worked at a profit.

10. *Partiality for new inventions, and too much disregard for the well-tried machines of old mining countries.*

The inventions and applications of the past should be known and remembered by inventors, and well proved modes

be used by miners, instead of re-commencing to improve in an old business, in a manner as if the whole affair had begun just here.

It is also liable to prevent the use of old machines and ideas, that should be common property of all, by such men's *unequitably obtained, patented claims*, which are difficult to set aside.

11. *Inexperienced, incongruous superintendents.*

Few men would be willing to take passage in a ship, if they knew that she was commanded by a dry-goods clerk, or other novice, who had not previously obtained some nautical knowledge and experience; yet many instances have occurred where the much more difficult business of mining has been superintended by such like men, who were utterly unacquainted with the various duties appertaining thereto.

Although these men have neither *innate superiority*, *practical ability*, *nor experience*, they, generally speaking, possess some *natural facility*, or *exterior fascination*, which procures them *confidence at sight;* and still manage to sustain themselves with superlative audacity, by placing their contemptible feet on the shoulders of the very men from whom their best information was either bought, borrowed, or stolen, during their continued struggles to keep their positions by this especial hoodwinking of their employers, who actually pay them for doing so.

SECTION V.

METALLURGY.

CHAPTER I.

ROASTING.

ROASTING OF PECULIAR ORES, TO REDUCE THEIR WEIGHT, FOR CHEAPER CONVEYANCE TO THE MARKET.—ROASTING, AND PARTIAL SMELTING, FOR REGULUS.—ROASTING FOR THE SEPARATION, AND PROCURATION BY CONDENSATION, OF THE VOLATILE ELEMENT, IN MARKETABLE PURITY.—ROASTING REFRACTORY ORES, PREPARATORY TO PLATTNER'S CHLORINATION METHOD FOR EXTRACTION OF GOLD.—ROASTING AND CHLORINIZING ORES, FOR MORE EFFECTIVE MILLING.—ROASTING INSOLUBLE ORES, FOR MORE EFFECTUAL CHEMICAL REDUCTIONS, BY VARIOUS HUMID PROCESSES.

Section IV completed the miner's avocation, as generally understood and practised in the old-settled countries, where division of labor is more judiciously applied for obtaining the greatest possible advantage for economical realization, under free trade international competitions.

In new countries, which, for local requirements, are worlds in themselves, unusual means *may be sometimes resorted to*, for considerable advantage; and these will be described in the following chapters of this Section, on Metallurgy, for such express purposes.

In these connections, it may be now most advantageous to consider why the miner should more generally prefer selling his concentrated ores, to *even far-distant* metallurgical companies, rather than completing their reductions on the mine?

And why this cannot be deviated from with some minerals, and complicated mixtures of minerals, with impunity, where greater profits and economy are the essential objects to be obtained?

Take as an example, for palpable illustration of this subject, any one of the large smelting works of South Wales, which are located either in, or close to, the coal and metal-supplying sea-port towns, which have steadily increased in size and importance, to accommodate the vast requirements of these gigantic firms, who have, in a manner, educated the whole community, of men, women, and children, to suit their peculiar manipulative purposes, for the production of coals, and reduction of minerals, to supply the metals to the whole world.

They have started from the very commencement of modern Metallurgy, and have, from their own and other people's inventions, so improved the chemistry of smelting, and secured the general confidence of the commercial world, that they can both command and supply all markets, for the following most salient reasons.

1. They have the most skillful supervisors that can be obtained.

2. A superabundance of capital.

3. An ample supply of cheap, educated operatives.

4. Coals, fire-clay, and brick, of the finest quality, at merely nominal prices.

5. Natural, costless chimney draught, and "reverberatory furnaces."

6. Many furnaces, for occasional repairs when required, and for the different treatments of peculiar ores.

7. Regular and cheap (return freight) supplies of all the varieties of minerals and matrices, from all parts, at home and abroad.

8. Systematic choice and assortment from all ores, to suit the ore that is being smelted, so as to improve the refractory by a more fusible and smeltable ore; or to enrich a smeltable lead by non-smeltable gold or silver ores; or by adding antimonial ore to lead, to produce more alloy, for peculiar markets; or adding one constitutional form of ore to another, to

produce certain chemical changes that may be desired during roasting, etc.

9. Smelting some tractable ores for pure metals, to supply as such.

10. Smelting other more mixed and refractory ores, for certain other markets, where purity is not essential.

11. Smelting mixed minerals, for alloys, to be sold as such for certain purposes, as copper mixed with tin or zinc, for bell metal, bearing brasses, brass, etc.

12. Humid reductions for the separate simultaneous precipitations of the artificial and marketable base minerals, and the silver and gold, for their individual markets.

13. A perfect knowledge and command of all the various requirements of trade, as well as where, and when, required; which is, in itself, an amazing advantage.

These are some few of the reasons why the miners, and even metallurgists, of this country, will not be able to compete with such firms, in the reduction of refractory minerals into metals. The cost of ocean freight (supposing the miner obtains a reasonable and just price for his ore) is a mere cipher against such advantages, coupled with your disadvantageous circumstances.

In many cases, it will therefore be much better to reduce the weight by suitable means, as will be described, for cheaper conveyance by land and water, than to complete the whole reduction into metal, on the mine

The many other adverse local reasons need not be portrayed, as they are already sufficiently well known to those mining and business men who have too hastily endeavored to run such unequal races.

The low-grade copper ores of Cornwall, which average from five to six per cent., are not smelted in the mines, but sent to South Wales, as return freight, at about from five to six shillings per ton, in the vessels that bring coals for the steam engines and domestic purposes of that county.

A respectable general firm is already needed, and will be much more required, in the City of San Francisco, for the judicious treatment of the various ores of the Pacific coast; and such a company should be either a feeding branch of one

of these larger establishments, or be fully prepared to either sell some of their ores in crude state, simply roasted, or partially smelted into regulus; whilst others may be smelted into commercial alloys, or into the pure metals, for the different markets.

Such a firm, if well and honestly conducted, would be mutually advantageous for the country, the miner, and itself; for millions of tons might then be mined and sold, by comparatively poor men, at paying prices, which, under present conditions, must lie unrealized.

The day cannot be far distant when such an establishment will be in operation; but it will not be complete unless it has these facilities, and also the milling, chlorinizing, and purely chemical treatments; so that every kind of ore may be beneficiated, to suit all circumstances and markets, after the best possible methods.

These different operations may be accomplished by small firms, for each separate manner of treatment; but lacking the miner's confidence, and the above general advantages of the one complete establishment, they will but serve the exceptional, rather than the general, requirements of miners, for some direct and especial object of the local manufacturer.

Lead, that also contains a sufficient amount of silver or gold, when wood is plentiful, may be occasionally smelted at a profit, on the mine.

Notwithstanding the above facts, many will most assuredly make the attempt; but few will succeed (at least for many years to come) in extracting more new dollars from the ore than the old dollars that will have to be expended in the smelting of the *other* base minerals.

The auriferous sulphurets of California may be considered as of but secondary importance to that of the quartz itself; for being directly derived therefrom during the regular milling process, from the simple concentrations, the heavy resultant residues of sulphurets of iron, copper, etc., may be readily roasted and chlorinized on the mine, *if in large quantity;* or forwarded to market and sold at fair value, for the gold contained therein; this being added to the more direct and primary amalgamated returns of gold from quartz, will greatly

enhance the profits, and in many cases realize gain, where loss will otherwise be the result.

Supposing the time (which is necessarily fast approaching) has arrived, when $5 quartz will yield good profits, if proper attention is paid to concentration, quartz that contains but one per cent. of sulphurets, which in themselves carry $500 of gold per ton (a not uncommon produce), it will be seen that they contain, even at this small percentage, as much gold as the quartz itself; and, at two per cent., even twice the value of the quartz from which they were concentrated.

The more the quartz veins are developed in depth, the greater will be the general percentage of such sulphurets; and as this kind of mining has but commenced in the State, amazing amounts of gold can and should be extracted therefrom by preliminary roasting, chlorination, etc., etc.

For the foregoing reasons, and the fact that the cost of carriage of even these unroasted sulphurets is trifling as compared to the gold they contain, it is very obvious that the miner and miller require a market for such, whether it be little or much that they have in stock, unless they have sufficient quantity to warrant the necessary outlay for treatment on the mine.

Large, well arranged, and properly conducted roasting and chlorination works will therefore be a most useful local auxiliary for the development of quartz mining on the Pacific coast, and undoubtedly profitable to those who may invest therein. Such may be established at San Francisco, or any other place to which routes for conveyance concentrate, and where labor and materials are sufficiently cheap, or in each large mining section.

The simultaneous productions of sulphur, sulphuric acid, and sulphates of iron, should not be forgotten in such works, as they are in local demand, and can be readily disposed of, at fair prices.

ROASTING OF PECULIAR ORES, FOR CHEAPER CONVEYANCE TO THE MARKET.

Auriferous Sulphuret of Iron—May be roasted in houses or heaps, *when not pulverized*, by being kindled, and occasionally urged by a small fire, so placed underneath that the

flames may, by passing up through the interstices, ignite the whole mass.

For this manner of reducing weight by fire, the ore must be from about the size of hen's eggs upwards, and the roasting is incomplete for any other purposes than those of reduction of weight, and the partial deposition of the volatilized ores, acids, etc., in suitable chambers, where it is sometimes hastened to precipitate by a shower, or very fine spray of water, as scattered from either a plane, or through a perforated plate, by following pressure.

Copper Pyrites—May also have some of its sulphur burned off, where fuel is plentiful, in a similar manner, by a stronger fire, so as to reduce its weight and increase its percentage of copper, for more profitable sale, arising from greater economy in its conveyance to distant markets.

This roasting is not necessarily complete, but carried as far as most economical for reduction of weight, and the formation of sulphide of copper matte.

Roasting and Partial Smelting of Copper Ores into Heavy Cupriferous Slag, "Matte," or Regulus.—In remote or interior sections of country, it will be often most advisable to first roast the different *sulphurets* of copper, either in the manner described, or still more effectually in a (say sixteen feet long by ten wide) flat-bottomed reverberatory furnace (which may be made of brick or fire-stone, similar to Cut 45); having a heat-supplying fire at the one end, two suitable side doors on each side, for stirring and exposing all parts of the ore to the action of the flames which pass over it from the fire, and one or more feeding holes at the top.

The parts that are exposed to the strongest heat should be either made of fire-bricks, laid on edge; of fire-rock, or fire-sand and clay; and the whole structure must be bound with external iron tie-bars.

After roasting these copper ores in this manner, they may be smelted into a heavy copper slag, in the same, or a similar furnace, by raising the heat and closing the side openings.

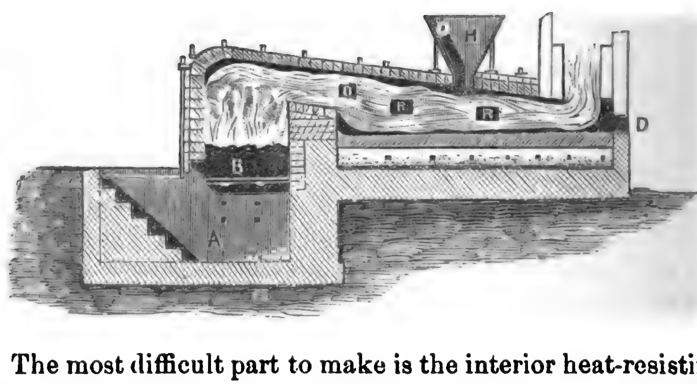
The draught is generally created by a high and necessarily very expensive chimney; but much more economically by *having the works near a hill's or mountain's slope, and cutting*

suitable chambers and ascending flues therein to some two hundred feet vertical height, to obtain sufficient draught for this and the other smelting furnaces.

Cut 45 represents a furnace that may be used both for roasting and partial reduction to sulphide of the metal. The ash-pit is marked by A; the fuel and fire-bars by B; the charging hopper by H; and the discharge by D. O are openings on both sides, for admission of air, whilst R R are raking holes, for turning the ore.

The lengthwise shape of the top, bottom, ends, and ash-pit, are shown in the section; but the general top may be strengthened by being slightly arched transversely, whilst that portion at the chimney *shown white* should be arched more strongly.

Cut 45.



The most difficult part to make is the interior heat-resisting bottom, which is usually done in this way. The inside lining of the fire parts, such as the sides, ends, and bridge of the furnace, must be first made of fire-brick set on edge, and being thus ready, all the openings at O, R, R, D, and H, may be closed, and the fire kindled and very gradually increased, for the purpose of drying the furnace thoroughly *It is now ready for ordinary roasting, and may be rendered fit for the smelting of copper into regulus in the following manner.*

The heat should be now increased, and a charge of two inches thick of slag smelted all over the bottom of brick. A layer of quartz sand of some sixteen inches thick is next

thrown on and equally distributed to a level; after this has been roasted for about three hours, it is allowed to cool; and then, after it has been pounded down to a level and solid state, another similar layer of slag may be melted on its surface; and a second layer of sand, of about four inches deep, being placed and beaten down to a level thereon, it is covered with about one inch thick of slag, which being properly fused, it is ready for actual smelting.

The fuel may be either wood, coals, or coke; and the furnace being built and gradually dried by a small fire, the roasting is performed as follows.

Charge fuel until the furnace becomes red hot, and then about four tons of the ore, which has been assorted and crushed in its dry state, by hand, or crushed by machine to the size of peas, and concentrated by the jigging machine.

The fire is regulated by a convenient damper, and supplied with fuel so as to play its warming influence over the whole length and breadth of the furnace-bottom; and when the ore begins to decompose, air should be admitted through the openings, O, which lie just over the bridge, to aid in the oxidation of the ore, which must be now stirred almost continually, by the insertion of rakes through the openings marked R, that are intentionally placed on either side of the furnace, until a sample of the ore (withdrawn through the end opening, D) ceases to smell strongly of the volatile element, when the whole charge may be withdrawn, for a repetition of the process on another batch of ore.

Great attention must be paid to the exact temperature that the different ores require for roasting, so as to obtain sufficient calcination without agglutination into a slaggy mass; which a little practice on any particular ore will decide.

This kind of roasting may be thus readily and beneficially performed on all the sulphide ores of iron, lead, copper, etc., where wood or coals is plentiful, so as to reduce their weights for distant delivery, and simultaneously prepare them for direct smelting or chloridation, which will enable many mines to give profits that cannot be made to do so if the *whole weight of mineral* has to be forwarded.

In some instances, the lead may be then advantageously smelted into metal, and copper be further reduced into a

regulus or "matte," in this same furnace, in the following manner.

To smelt into the desired matte, about two tons of the roasted ore may be mixed with one ton of raw ore, and a little fluor spar or quartz (if there is not enough in the ore), to form a fusible slag.

Oxides and carbonates of copper may be added to these, and smelted without any preliminary roasting.

The whole must now be charged into the hopper, which being allowed to drop into the furnace by the withdrawal of its underlying iron slide, it is spread over the bottom, and after the holes, O, R, R, D, and H, are closed perfectly tight, the fire is urged to its utmost heat for some five hours, until the whole becomes at a white heat and in perfect fusion, as seen through small holes in the end and side doors.

The end door may now be opened, for the purpose of passing a long-handled hoe through the mass, for testing its fluidity. If found thoroughly fluid, it may be allowed a few minutes to settle, before the upper and lighter scoriæ is very carefully drawn off, through the doorway, by the long-handled hoe. In this withdrawal of the slag from the underlying heavy matte, great care and skill is necessary, so that no portion of the lower stratum shall be also withdrawn. The large smelters generally charge ore once more, for a second smelting at this stage, before the matte is tapped off, which is done by removing a clay stopper from a suitable side hole at the lowest part of the pool, with a tapping bar. For the purpose of carriage, this molten matte may be cast into suitable ingots or bricks.

ROASTING OF TIN OXIDE, AND REFRACTORY MILLING, SILVER AND GOLD ORES.

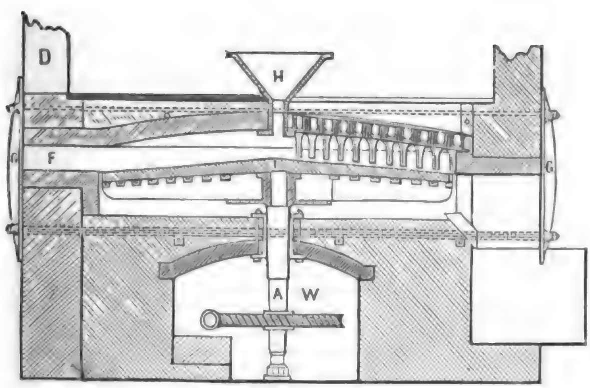
The ores must be first reduced by battery, *without water*, to an almost impalpable dry powder, when they may be roasted, where labor is cheap, in the manner described under the preceding heading, in the furnace (Cut 45).

Many variations have been made in roasting furnaces, and almost every conceivable shape and manner of manipulation tried; but where cheap labor prevails, and persistent roasting is necessary, the old miners generally return to the reverbera-

tory "hand-rake" furnace, both when the present simple roasting is only required, as well as for the subsequent chloridation of silver ores, to be described under its proper heading, towards the end of this chapter.

Where educated labor is dear, the Cornish revolving table stands in good stead (as illustrated by Cut 46), where a convexed iron table is covered with bricks, and supported by the axle, A; it is revolved by a water-wheel, which is attached on to the axle that works the worm-wheel, W, and the roasting table at any desired speed, with clock-like regularity; whilst the pulverized dry ore falls through the hopper or funnel, H, on to the table; where it is then turned over and over, and outwards, by the ten movable stirrers that

Cut 46.



point down over the table, at any desired angle, to more or less accelerate or retard the properly heated ore, and thereby cause it to fall over the table and through the shoot, down into the receiving-box platform seen at the right of the cut.

The ore may be heated to the proper degree by one or more fires, not shown in the cut, because the one lies a little short of, and the other beyond, the plane of section at the right of the figure, just in level with the table, so that the heat may pass all over the ore, *en route* through the discharging flue, F, to the chimney, where a good damper regulates the heat as required for simple roasting or chloridation. The stirring rudders may be fixed in two or three radial lines from the centre, so that the ore may be turned over twice or

thrice during the round, as they work on *each other's ridge:* the stirrers pass up through the roof, for regulation from without.

It will be seen that this roaster is as simple as it is efficient, as nothing is necessary but to charge the fuel and ore in a regular manner.

The mineral is thrown through the doorway, D, on to the iron plate shown; then mixed and fed through the funnel-mouth into the furnace, where it is regulated in heat, and time of passage, by the fires, the stirrers, and speed of table, to any degree of nicety.

There is still another old machine roaster, which is made somewhat similar to the coffee roaster, but lined with brick, either in a regular or irregular tooth-like manner; it is made of proper length, and so sloped that the time occupied for its transit through the heat shall suit the requirements of the ore under treatment. About twenty feet in length, and two feet in internal diameter, is a useful size for ordinary quantities of ore. This cylinder may be revolved by a small water-wheel, at any desired speed, and the fire may be either in the lower revolving end, or beyond it, and flued to communication therewith. The ore is fed through a diagonal hopper or funnel at the upper end, in powdered condition; and, during the cylinder's revolution, it is being continually elevated on the one side to fall towards the middle, through the heated gases, at a point somewhat nearer the lower end, where it escapes under the flue from the fire. If it is necessary to repeat the roasting, the ore may be re-conveyed by a screw elevator to the charging funnel for that purpose.

The worst objections to this furnace are that the power required for the continual elevation of the whole weight of ore so repeatedly is somewhat considerable, for large-scale operations; there is a difficulty, too, in making the end joints from the fire, and to the flue, sufficiently tight; and the lining of bricks is liable to become loose, as the shell increases in size, from the heat. Whatever furnace may be used, large reservoir chambers may be advantageously applied for retaining the base metal oxides, as they are volatilized from the fire.

ROASTING FOR THE SEPARATION, AND PROCURATION BY CONDENSATION, OF THE VOLATILE ELEMENT, IN MARKETABLE PURITY.

THE BENEFICIATION OF THE ORES OF MERCURY.—The most prominent in this class are treated in the following manner.

The sulphuret of mercury (or cinnabar) is the usual ore, which is intimately mixed with quick-lime (according to the quantity of sulphur which it unites with), and then roasted during frequent stirring at a low red heat, until the whole of the mercury has been volatilized. The fumes of mercury thus released by sublimation from the ore are precipitated by condensation, during their retarded travel through iron chests, to run out through suitable orifices into iron, glass or stone wells; for being filled into stoppered iron bottles, for more convenient sale.

The most favored method in Europe, as directed by Dr. Ure, is to sublime the mercury from the mixture of ore and quick-lime, from iron retorts, in manner similar to retorting coals for coal gas, and to condense in iron chambers, and amidst a spray, shower, or falling river of water.

In this country, the mineral has been roasted in cupola, or reverberatory furnace fire, and condensed in iron chambers.

The most ready, certain, and cheap means for burning off the mercury is probably the reverberatory furnace, as it can be made sufficiently capacious that charge after charge can be introduced through the hopper, and beneficiated without any of the fumes escaping to poison the men. This furnace requires but occasional clearance of the gangue.

It is also probable that Hall's condenser, as formed by a numerous series of *small and very thin* iron tubes, placed in vertical or diagonal position, and *surrounded by running water*, will answer superlatively well for its *effectual* condensation.

Sulphur is separated from its gangue, and condensed in a similar manner, in one or more large receiving rooms.

THE COLLECTION OF THE VOLATILIZED OXIDES OF ANTIMONY AND LEAD, ARSENIC AND SULPHUR, FROM ORES, BY RETARDATION AND CONDENSATION, IN CHAMBERS, AND BY PRECIPITATION IN SHOWERS OF WATER.—*All these, whether they may result from smelting or roasting,* may be caught in large chambers, or rooms, during their passage to the chimney, or sloped hill-

side flue, which may be sometimes facilitated by allowing a stream of water to fall through a large perforated plate, to meet and precipitate what might otherwise escape.

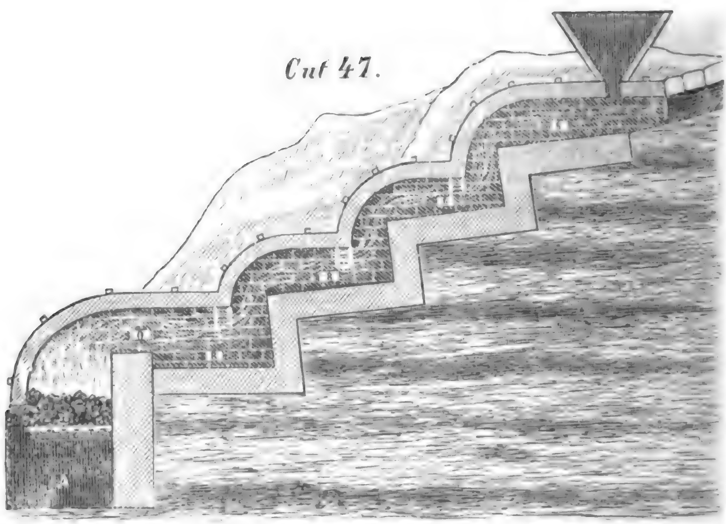
The receiving chambers may be cleared through the suitable doors, as often as may be found necessary.

As nearly all the American mines are situated on the acclivities of mountains, it will be most convenient to erect these roasting and smelting "reverberatory furnaces" on the side of a rather steep slope, to save the expense of chimney, arresting houses, etc., etc., as the flues and houses may be excavated in the ground, and be covered by rock, to save the much greater expense of building them.

ROASTING OF REFRACTORY ORES, PREPARATORY TO CHLORIDATION FOR GOLD BY PLATTNER'S PROCESS.

1. I would suggest the arrangement of the reverberatory hand-furnace shown by Cut 47, as a cheap and efficient roast-

Cut 47.



ing and chlorinizing furnace, where the mines are located on the slopes of hills or mountains.

The letters serve to explain the different parts, as before, for Cut 45; and it will be observed that steps and hearths are placed each higher than the other, so that the pulverized ore may be charged through the funnel to the upper one, for

preparatory warmth; and being raked transversely through the side door, it will *naturally descend* over this *inclined hearth*, and ultimately fall through the heated air to the next of the series (or through the chlorine gas, when it is desirable to chlorinize for the subsequent extraction of silver by pan or chemical process). Under the foot of each sectional arch, there should be transverse arches, as shown by the descending lines beneath, for supporting the roof; and the whole should be firmly secured by external bolts, as shown. To suit less refractory ores, *other funnels* may be placed over *each lower hearth*, so as to use but one, or more, as required.

All of the bed part may be of fire-bricks, or fire-rock, if more easily obtained; or good common brick may be made to answer for the bridge, hearths, and roofs, as the heat is but moderate.

The foundation is cut in the side of a hill, of suitable shape for the hearths and ash-pit, and the draught is obtained by simply cutting and covering a trench up the slope of the hill, so that no other chimney is required. Catch-houses may be also excavated, when required for the arrestation and collection of the volatilized elements.

If there are no other advantages than that of warming the ore, as it lies on and falls from hearth to hearth, by otherwise wasted heat, it is considerable.

The ore should be charged in sufficient quantities as required, for being properly raked to fall at suitable speed through the series, to suit the strength of ore, as governed by fuel and damper; and nothing but time and occasional stirring is necessary. The ores may be stirred on the *upper inclined hearths* by transverse rakes, as worked by machine motion, on bars that pass clear through both walls, to guide and carry the rakes across the furnace at their middles, so that the ore may fall down the incline after each motion.

2. *The Cornish calciner may be used with great efficiency for this roasting* (as explained by Cut 46).

The ore is charged in pulverized dry condition, through the hopper or funnel, H, after the furnace has been brought to suitable temperature, which varies from low red to red, and yellow red, according to the constitution and associates of the ore.

It is regulated in its travel from the centre, as already explained, both by the varying speed of the rotating hearth, as worked by more or less water on the driving wheel, as well as by the stirring knives that can be also governed or varied from without.

It will be seen that it is being continually turned over in its passage from the centre outwards, until it falls over its periphery by way of a suitable lip to the receiving plat.

Now it should be examined to prove if the roasting has been complete, by its smell, or by the other means that have been fully described in the chapters on discrimination of all the useful elements; or more immediately to the alphabetically arranged chapter, for more prompt general reference.

The roasted ores should be deposited in a place where they can be soused in water whilst hot, to wash away the soluble matter, and extract more sulphur by the formation of sulphide of hydrogen, which can be readily known by its foul smell.

There is but one object for this roasting, which is the volatilization of the deleterious element, so that the gold may be released; but this must be effectually performed, and cannot be hurried beyond certain limits.

It is very evident that the effectual calcination of even moderately stubborn ores cannot be performed by the *magic of any instantaneous process*, for the substantial reasons that at least *a quarter of an hour is required for the roasting of either an arsenical or sulphurous ore, in minute quantity, even when mixed in the roasting cup, with the powerful auxiliary of pulverized charcoal*, although it may be *stirred for the whole time*, in an *appropriately* heated muffle, where pure and free *hot oxygen* from the air has access; and, on the large scale, from six to twelve hours is required for the effectual roasting of one batch.

It is a noteworthy fact, which should be well considered, that after repeated trials of all the innumerable more complicated devices for the acceleration of roasting, the large metallurgical establishments of Europe have still retained the one or the other of the forms of reverberatory furnace.

Therefore, cheap labor should be obtained, to realize from such, more simple furnaces, better results.

It is to be regretted that patent rights can be obtained too

readily in new countries, for the every-day appliances and variations of principles long used by workmen in the private establishments of old countries.

The public should form a collective protection league, to sustain individuals when using simple natural means to attain an economical end. **For what law can reasonably debar any** man from the use of fire, for roasting in any manner; or water as a solvent, in any case? Such prohibitions are public misfortunes, which should not be allowed.

After observing the innumerable devices in Europe for calcination, an eminent authority, Dr. Ure, says:

"The reverberatory furnace affords one of the best means of ustulation, where it is requisite to employ the simultaneous action of heat and atmospherical air to destroy certain combinations, and to decompose the sulphurets, arseniurets, etc. It is likewise evident that the facility thus offered of stirring the matters spread out on the sole, in order to renew the surfaces, of observing their appearances, of augmenting or diminishing the degree of heat, etc., promise a success much surer, a roasting far better executed, than by any other process. It is known, besides, that flame mingled with much undecomposed air issuing from the furnace, is highly oxidizing, and is very fit for burning away the sulphur, and oxidizing the metals. Finally, this is almost the only method of rightly roasting ores which are in a very fine powder. If it be not employed constantly and for every kind of ore, it is just because more economy is found in practising calcination in heaps, or on areas enclosed by walls; besides, in certain mines, a very great number of these furnaces, and many workmen, would be required to roast the considerable body of ores that must be daily smelted. Hence there would result from the construction of such apparatus and its maintenance a very notable outlay, which is saved in the other processes.

"But in every case where it is desired to have a very perfect roasting, as for blende from which zinc is to be extracted, for sulphuret of antimony, etc., or even for ores reduced to a very fine powder, and destined for amalgamation, it is proper to perform the operation in a reverberatory furnace. When very fusible sulphurous ores are treated, the workman charged with the calcination must employ much care and experience, chiefly in the management of the fire. It will sometimes, indeed, happen that the ore partially fuses; when it becomes necessary to withdraw the materials from the furnace, to let them cool and grind them anew, in order to re-commence the operation. The construction of these furnaces demands no other attention than to give to the sole or laboratory the suitable size, and so to proportion to this the grate and the chimney that the heating may be effected with the greatest economy.

"The reverberatory furnace is always employed to roast the ores of precious metals, and especially those for amalgamation; as the latter often contain arsenic, antimony, and other volatile substances, they must be disposed of in a peculiar manner.

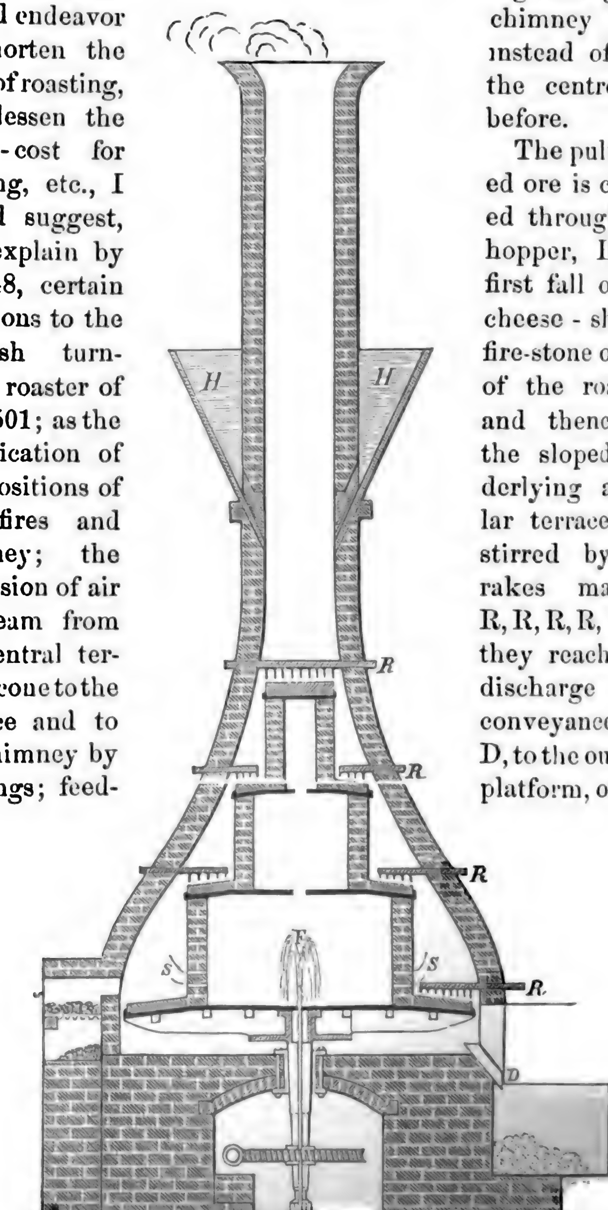
"The sole, usually very spacious, is divided into two parts, of which the one farthest off from the furnace is a little higher than the other. Above the vault there is a space or chamber in which the ore is deposited, and which communicates with the laboratory by a vertical passage; which serves to allow the ore to be pushed down, when it is dried and a little heated. The flame and the smoke which escape from the sole or laboratory pass into condensing chambers, before entering into the chimney of draught, so as to deposit in them the oxide of arsenic and other substances. When the ore on the part of the sole farthest from the grate has suffered so much heat as to begin to be roasted, has become less fusible, and when the roasting of that in the nearer part of the sole is completed, the former is raked towards the fire-bridge, and its ustulation is finished by stirring it over frequently with a paddle, skillfully worked, through

one of the doors left in the side for this purpose. The operation is considere to be finished when the vapors and the smell have almost wholly ceased; its duration depending obviously on the nature of the ores."

For those who would endeavor to shorten the time of roasting, and lessen the labor-cost for stirring, etc., I would suggest, and explain by Cut 48, certain additions to the Cornish turn-table roaster of page 501; as the modification of the positions of the fires and chimney; the admission of air or steam from the central terraced cone to the furnace and to the chimney by openings; feeding through the chimney itself, instead of over the centre; as before.

The pulverized ore is charged through the hopper, H, to first fall on the cheese-shaped fire-stone on top of the roaster, and thence to the sloped underlying annular terraces, as stirred by the rakes marked R, R, R, R, until they reach the discharge and conveyance lip, D, to the outside platform, on the

Cut 48.



[Patent applied for.]

right of the figure. The rakes are shown as if made of iron, but may be made of fire-stone, suitably perforated for receiving similar teeth, and so built in the wall that they can be replaced at pleasure. The bed bricks may be also moulded of suitable segmental shape for the purpose.

On the left side is shown one of three, or five, small equidistant fire-places, which give heat to all portions of the lower hearth; whilst, as the heat is used up, the remainder concentrates during its ascension to the smaller space, and thereby the ore is more effectually roasted throughout the whole descent, by this equalization of temperature.

A jet of water is made to pass up through the hollow axle, which, falling into a trough on the lower bed-plate, serves the purposes of keeping the iron comparatively cold, and for the formation of steam to pass out through openings just over the bottom, or the several terraces for facilitating the decomposition of the ore. To prevent fracture, the bottom plate may be made of a part wrought and part cast-iron.

Or air may be passed through instead of steam.

THE ROASTING AND CHLORINIZING OF THE MIXED ORES OF SILVER AND BASE METAL, FOR MORE EFFECTIVE AMALGAMATION.

Before building roasting and chlorinizing furnaces, you should carefully examine the general average of the ores, by actual analysis, so as to know its exact constitutional form; for some ores can be milled cheaper (after deducting the expenses for roasting and chloridation) without roasting, than with it; whilst others, being easily roasted, may be treated in a more expeditious manner than the refractory, fire and time-resisting ores. So, also, regarding the counteractions that may be produced by the base minerals and alkaline earths; which, by uniting with chlorine, form volatile, and soluble or insoluble chlorides; and by union with sulphur and oxygen, the soluble or insoluble sulphates of the metals and lime; which analysis not only rules the necessary amount of sulphurets for combination with these, in addition to that required for releasing chlorine from the salt by similar union, but directs you to the best means for beneficiation.

The previous roastings were intended either for the partial or complete removal of the volatile element, or for its sepa-

ration by sublimation and precipitation for the market, by slow travel and condensation; but *the objects now to be obtained* are, first, the separation, and *condensation too*, if necessary, of the volatile element, and the *subsequent union of the metal or metals with chlorine gas.*

In furnace chloridation, the following facts and hints should be remembered.

1. The chlorine gas is obtained by the union of sulphur (*released from sulphurets*) with the oxygen *of heated air*, and the sodium of the salt, which form sulphate of soda, and chlorine gas is simultaneously liberated.

2. A sufficient *amount of sulphurets* (or a substitute, as *sulphate of iron*) must be present in the ore (or be added), *as well as salt*, to expedite the formation of the necessary gas.

3. These salts must be very much in excess of the nominal equivalent quantity against that of silver, as much passes away through the chimney.

4. The salt must never be less than some six per cent., and as much as twenty-five has been sometimes used.

5. The sulphurets present must be *more than equal* to the salt and all the other base metals and alkaline earths (as lime, etc.), with which it also forms sulphates at such temperatures. *The salt and sulphurets should be mixed and crushed with the ore.*

6. The chloride of silver is, for practical purposes, non-volatile; whilst many of the base metal chlorides may be passed off by a lengthy roasting, at elevated temperature.

7. The chloride of silver thus obtained is insoluble in water, whilst many base metal chlorides are soluble therein; so that they may be thus economically separated, the latter passed away, and the former precipitated as in the method of Becchi and Haupt, and the roasted matte amalgamated as at Cziklowa, in Hungary.

8. Ores which contain much lead or antimony must be stirred in a continuous manner, at a low red heat, during the greater part of the time; but towards the close, and during the chloridation stage, it may be allowed to rest for a few seconds, between the stirring periods, for more effectual combination from actual contact.

9. As regards the proper heat, it may be considered to vary with the different ores; those of lead and antimony require a moderate initial and steadily increasing heat for completion; the constitutional silver ores require a moderate heat, for chlorination is the desideratum, for if reduced to metal, amalgamation is retarded; so when the base metals can be partially or entirely passed off as volatile chlorides, protracted roasting at increased temperature is beneficial.

As a rule, provided the ore can be kept in a pulverulent condition, the higher the temperature the more expeditious and complete is calcination, and perfect the chloridation.

10. In roasting, the heat is regulated both by the damper and by the position which the ore occupies on the hearth. The colder portions may be moved by a long-handled scoop or flat shovel to hotter positions, whilst that which is already too hot may take its place; the whole being stirred with a rake when necessary.

11. There is one particular action which transpires after the sulphurous acid is formed, that must not be underrated, and which requires both stirring and quiet. The stirring, by exposure to the hot air, oxidizes the sulphurous acid into sulphuric acid, which, in falling on and into the pile during the operation of stirring, unites with the sodium of the salt to form sulphate of soda, whereby the chlorine is released in numerous globules of gas, and being confined, as it were, in the same cell with the silver, it is compelled to unite there-with, as well as with the base minerals, that of silver being insoluble, whilst those of the base minerals are mostly soluble in water.

A. *The percentage of sulphurets in the ore may be found* by weighing, from a careful average sample, 100 grains, examining, concentrating, and separating it by water, after the manner described in Chapters III, IV, and V, Section III.

B. Or by dissolving it in three parts of hydro-chloric and one part of nitric acid, by boiling the solution for two hours, and then filtering the watered solution, for precipitation by chloride of barium as sulphate of baryta, which may be collected on a balanced filter, dried, and weighed. Every 100 parts or grains of this "sulphate of baryta" contain 34 of

sulphuric acid; so that you may know your percentage of sulphuric acid by multiplying the weight of sulphate of baryta thus obtained by 34, and dividing it by 100.

C. To the 100 grains of ore taken for assay add 100 grains of borax glass, 100 grains of common window glass, and 2 grains of resin, all finely pulverized and intimately mixed. Smelt in a crucible for twenty minutes, at a yellow-red heat; withdraw, and allow the contents to become quite cold. This forms a sulphide of iron button of heavy matte, which affords an approximate means for estimating the quantity of sulphur the ore contained. In the refractory ores, the weight of this matte should be some thirty per cent., or sufficient must be added thereto; but where the ore is of more simple form, as containing constitutional forms of silver, that are comparatively free from base minerals, alkaline earths, etc., a much less quantity will suffice, for reasons previously explained.

D. Treat (after the addition of some charcoal) as directed at the foot of page 348.

It is advisable, for greater certainty, to have a reasonably safe excess of sulphurets and salt; but as any very great excess is superfluous and expensive, it will be desirable to make assays from different mixtures of such, so as to know if the whole of the silver has been chloridized.

This assay for chloride of silver may be made in four ways, sufficiently near for such purposes; or it may be proven in the large way, by amalgamation, on the differently mixed quantities.

1. *Comparative assay from the difference of silver obtained, as made by fire and by acid.*

Take 100 grains of the finely powdered, chlorinized ore, and assay it as directed for the crucible or scorifier, in Chapter VII, Section III.

Then take a similar quantity, place it on a filter, and pass a continuous current of pure water over and through the mass, until there can be no possible doubt that the whole of the salt has been dissolved out (which may be tested by nitrate of silver solution).

Now place this filter and its contents in a glass vessel or

porcelain cup, and pour thereon about twice its volume of nitric acid (which will not dissolve the chloride); and after completing the solution of all but the chloride, filter and precipitate the silver from the solution by salt, then weigh and calculate as directed under the heading for humid assay of silver.

2. Collect this chloride on another filter, dry, burn off, and flux, for crucible or scorifier, and after smelting and cupelling as before, the difference in the buttons will equal the soluble portion, and the loss by the insufficient chlorination.

3. It may be tested after the large scale manner of Von Patera, as described in Chapter V of this Section (if you have the re-agents), and again smelted for difference.

4. It may be ascertained by a preliminary fire assay, as by heading 1, and careful observation of what is actually obtained from pan or barrel, which cannot be expected to realize much more than ninety per cent. of the fire assay.

ROASTING INSOLUBLE ORES, FOR MORE EFFECTUAL CHEMICAL REDUCTIONS, BY VARIOUS HUMID PROCESSES.

In addition to the roastings described under the past headings, there is still another principle, first utilized by Ziervogel, for extracting silver from copper sulphide matte.

It is very economical and effective, but difficult for execution by inexperienced hands.

The matte or ores, as may be, are carefully roasted and stirred, in a gradually increasing heat, for some ten hours, which produces certain succeeding changes, as follows.

Iron and copper lose sulphur, and become sulphates, and then oxides; then the sulphide of silver also changes to a sulphate, and, the heat being continued, into oxide; and then, on a slight increase of temperature, the latter becomes reduced to metal.

The skilled workman is, however, enabled to withdraw the charge just when the silver is in a state of sulphate, which is soluble in water, and thus it may be tested by precipitation in a cup, saucer, or glass, by salt, or other re-agent.

It has been much used since the workmen have acquired the necessary skill for more correct manipulation, and will be more particularly described in Chapter V of this Section.

CHAPTER II.

MILLING.

THE MILLING OF GOLD BY BATTERY, WITH WATER AND MERCURY. THE MILLING OF GOLD AND SILVER IN DRY STATE, BY BATTERY, FOR SUBSEQUENT ROASTING AND FINAL TREATMENTS BY BARREL OR PAN AMALGAMATION, BY CHLORINATION WITH PLATTNER'S PROCESS, AND FOR OTHER CHEMICAL MANIPULATIONS.—MILLING WITH IRON PANS; IN COPPER-BOTTOMED PANS; IN ARRASTRAS; IN THE CHILIAN MILL; IN ARTIFICIAL STONE ANNULAR PANS; IN CLOSE REVOLVING BARRELS; AND WITH VERY HOT WATER, AS CREATED BY HIGH PRESSURE.

The term of "Milling" has the ordinary meaning of grinding to a dry powder; but, in this mining sense, it must be extended to the wet process, where *water* facilitates the amalgamation of gold and silver ores with mercury.

As no man can know how to treat the ever-varying ores by visual discrimination, it is absolutely necessary that an examination should be made, to ascertain its constitution, previous to manipulation, so as to know if it be a simple ore; or whether preliminary roasting will be necessary for removal of sulphur, arsenic, etc.; or if it is an ore that contains much of the smeltable metals, as antimony, copper, or lead, in which the precious metals are constitutionally refractory, and more especially antagonistic to the milling process.

Those who are not acquainted with chemical analysis will find Chapters III, IV, V, and VI, on "Discrimination," and the following chapters of Section III, on the actual assay of known minerals, all-sufficient for their purpose. Or an analysis of a well assorted average sample prepared as in Chapter I, Section III, should be obtained from a professional man.

Before entering into the details of the various milling

manipulations, it may not be amiss to quietly consider why gold quartz has been worked much cheaper elsewhere than in California.

SOME OF THE REASONS WHY GOLD HAS BEEN EXTRACTED FROM QUARTZ MUCH CHEAPER IN AUSTRALIA THAN IN CALIFORNIA.

There are many reasons, beyond the slight differences of manual wages, why auriferous quartz has been and is still being worked cheaper in Australia, New Zealand, etc., than in California; which should now be retrospected and interviewed, for future advantage.

The first great gold excitement of Australia was caused by the discovery of frequent nuggets of gold, by trifling amounts of labor, in the water-washed gulches of the District of Forest Creek; which caused a general rush of people from its more immediate vicinity. The subsequent discoveries, made by more extensive explorations, sustained the first results, and increased the excitement, until British people from at home, and throughout all the world where their flag waved, as well as men from all other nations, concentrated in great numbers to this El Dorado, to realize prompt fortunes.

The surface gold soon becoming scarce, pits were next sunk to find the ancient river channels, and washed debris, when the whole district was soon discovered to be more or less auriferous; that the present shape differed much from the original contour, and therefore, as so little could be known from mere visual surface examination, nothing short of shaft-sinking would answer the purposes of discovery and extraction; so that the skilled miner soon became a necessity for such mode of working.

The uneducated workman from the outside world would naturally fail in sinking the many most difficult shafts that were continually required, and would therefore, however reluctantly, have to succumb to the skilled miner, who would be at a high premium, and many miners' fortunes have been made by *continuing such abandoned sinks*, to the deeper and *profitable streaks*, in and under these ever-varying alluvions.

Other similar districts were soon found; so that this became a very important branch for skilled labor; the quali-

fied workman had to lead the way, was respected accord ingly, and this increasing demand, with consequently high wages, brought great numbers of experienced Cornish miners into the country.

After these richly nuggeted fields became somewhat exhausted, these men gradually and carefully considered the subjects of auriferous "tailings" and former "leavings," as well as the quartz veins, and did not run crazy after new ideas in all things appertaining to mining and metallurgy; nor did they reverse the whole affair, by becoming solely metallurgists, and erecting metallurgical works where insufficient or no quartz or auriferous debris had been proven to exist; for having been educated in systematic mining, in a school where all practical problems are worked on well proven maxims, derived from the experience of many ages, further enhanced by the perfected and appropriately contrived mechanisms of many of the best engineers that ever lived, and manufactured by the first mining founders of the world: they looked at the true position of affairs, and selected proper machines, as made by, and supplied from, hese Cornish foundries (which served as examples for the subsequent colonial foundries). Thus, by proper arrangement of the works, division of labor, economy, and practical houldering of their own wheels, they have been generally successful where success would not otherwise have resulted.

The cost for mining and milling in Australia is of an *uniform* lowness of figure (ranging from about $5 to $2.50 per ton); whilst that of California varies exceedingly (from $15 and upwards to a minimum of $4.50), as more particularly governed by difference of supervisive skill, position, hardness of the rock, etc.

This is more to be attributed to the fact that the quartz of Australia has been almost universally manipulated by men who had been previously engaged in mining during their whole lives, and who would consequently approach nearer to equality under similar practices and well proven machines, than men who, being more or less new to the business, practised all manner of operative developments, and tried innumerable new schemes and conceits, instead of relying on, *or at least first using*, those that had been thoroughly

proven by the older mining countries. It is a palpable fact that the developments of the mines of the United States have been unnecessarily retarded by far too many experiments with peculiar processes.

There are, moreover, certain inherent feelings amongst the capitalists and practicals of old countries (not existing here), which favor division of labor; they also show proper respect, and give fair values, to the men who have expended many years of mental and physical exertion to obtain an ample knowledge of the secrets and practices of any one particular business, in the many divisions of professions and trades amongst mankind; and therefore few men can be found sufficiently defiant of public opinion, and conceited in themselves, to undertake any business or trade to which they have no such generally recognized title; the miners of Australia being thus morally strengthened, led and guarded the way to more regular results than have generally prevailed in the more cosmopolitan United States of America, where the people, although much longer established in most other businesses, more generally intelligent from their universal system of education and peculiar natural inquisitiveness, have been until very recently almost entirely unpractised in that of mining.

The United States of America was in early times suddenly surcharged, and the business people deceived and overruled, in this new and peculiarly difficult business, by metallurgists and metallurgical pretenders, who, living in the cities, at the elbows of capitalists, too easily obtained their confidence, and caused various, innumerable, and worthless machines to be forwarded for the extraction of what had not been discovered, or at least laid sufficiently bare for even probability of continuance; and such men, their friends, some dry-goods clerk, or the like, generally managed to proceed therewith, to superintend the works; therefore, under such circumstances, nothing could have been expected but the worst extravagance, and certain ruin.

The distant, hard-working, and experienced miner, laboring under the disadvantages of absence and minority, thus illegitimately supplanted, despised in his own business, and submerged in contumely, took no interest in development,

but merely endeavored to do as *little as possible of work*, and to find a solitary pleasure in laughing at the general mismanagement of affairs, until the dropping of the curtain at the termination of the burlesque.

Mining should precede metallurgy, and reduction works be firmly withheld until no possible doubt exists that the proper quality and quantity of the mineral can be obtained.

From these initial advantages, which engendered the following most imperatively essential differences, they have obtained more regularly economical and superior results, in both mining and metallurgy.

1. They have mined systematically, and practised the greatest possible economy of labor and material, in all ways after the methods described in the chapters on mining.

2. The quartz should be passed from the mine (when necessary) directly into a rock-breaking machine, and thence straight into the mill, by a large tram-wagon, drawn by a horse or mule, over a double or switch track, as driven by a boy, or other cheap labor; and so that as little shovelling as possible may be required, suitable tip or dump-plats should be provided at all the termini, the first terminus from the mine being so arranged that the quartz may be discharged into the empty car whilst the full one is being transferred to the battery. The rock-breaker should be also so placed as to discharge its debris into other similarly arranged wagons, for conveyance to the battery. In suitable places, a horizontal or vertical pulley may be placed at the top of the incline, so that a rope can be attached to two balanced wagons, where the full car will, during its descent, hoist the empty wagon for another cargo, as regulated by the brake; or the patented clip pulley of John Fowler & Co., of London, may be used, either with or without power. In a comprehensive and completely illustrated circular, dated 1865, they describe it as follows:

"The experience gained by John Fowler & Co., in the use of wire rope when cultivating land by steam power, and the encouragement given them by the saving effected in wear of rope through the use of their patent clip pulley, has induced them to lay before the public a few arrangements for its use as a means of haulage in mines, or wherever wire rope is used for transmitting power.

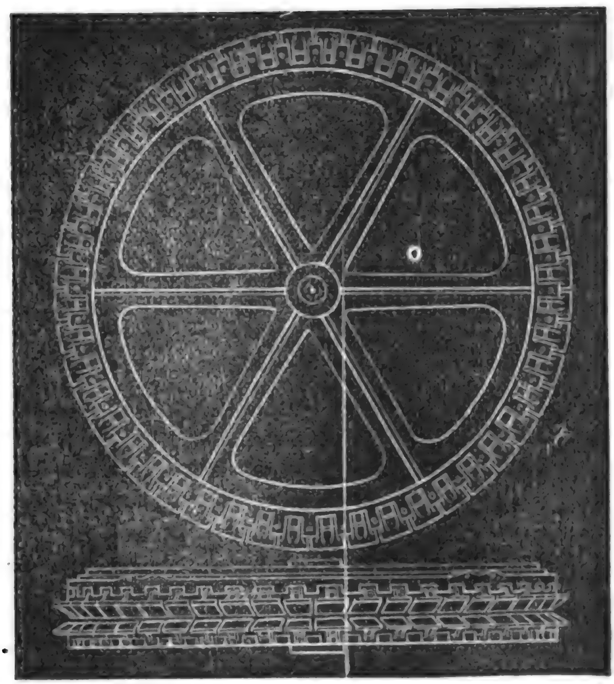
"These pulleys have been in regular use for steam cultivation for the last four years, and upwards of four hundred of them are now working, with an *actual draught* on the rope varying from one to three tons; many of them are also now being used in mines with the greatest success. John Fowler & Co.

have therefore great confidence in recommending them to those who are using wire rope in any way.

"The *patent* clip pulley has many advantages; the rope lies in a perfectly smooth groove formed by the clips, which prevents all overlapping, and also that jerking motion so destructive to the rope when coiling. A smooth surface of the rope is maintained, and no short bends with flattened pieces (caused by overlapping) will be found. When passing over the pulley, the action of the clips on the rope tends to distribute the load more equally through the wires, and less rope is required with these pulleys than with coiling drums.

"When working roads with irregular inclines, either self-acting or with power, by these pulleys, with a brake attached, the brakesman has the most perfect control over the load, and can stop almost instantaneously. Instances have occurred where, by the breakage of the rope, one train has been held by the pulley, the brake being promptly applied by the man in charge, thus saving half the damage that would otherwise have occurred.

Cut 49.



(No. 1)

"It is the only practicable way of conveying power to a distance, for working pumps, etc., by means of an endless wire rope.

"For temporary haulage, a portable engine has been arranged, with the clip pulley attached, which saves considerable expense in fixings.

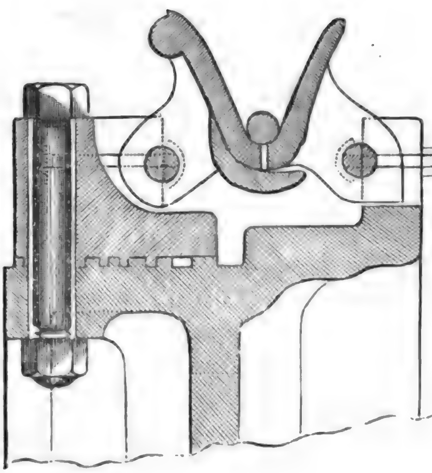
"With these various advantages in its use, John Fowler & Co. invite an inspection, and a trial.

"No. 1 represents a complete pulley. It can either be mounted on vertical or horizontal axes, but preference is given to the former plan, inasmuch as in some horizontal positions it is necessary to pay the rope on to the under side of the drum, which is not so convenient when the reverse action is required. * * *

"No. 2 shows a section of the pulley. It will be observed that it is made in two parts; the one forms the main casting with arms and boss, carrying the

centres of one row of clips, and forming half the groove of the pulley; and the other is a flange or ring carrying the lower row of clips. This is screwed on to the main casting in a similar way to a nut and bolt (as shown), and thus gives an adjustment between the centres carrying the clips which admits of ropes of various sizes. There are through bolts to prevent the ring from shifting on the main casting.

Cut 50.



(No. 2.)

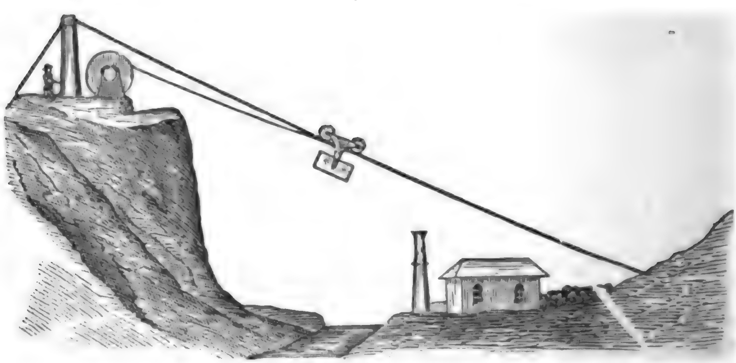
"The clips are cast with chilled surfaces, which prevents wear in the groove; and as in their action, when the strain comes on the rope, they move towards the axis of the drums, there is no surging of the rope against the clips, which is the means of reducing both wear of rope and drum.

"The hold of the rope by the clips is increased exactly in proportion to the pull, and the nearer the centre of the rope comes in a straight line with the centre of the clips, the more securely the rope is held: but, in working, it is found desirable to allow the rope to go no further back than will give sufficient hold to keep it from surging

"In looking at the section, one important advantage the pulley has, is the way it takes hold of the rope. In a flat-bottomed pulley, there is a continual movement amongst the wire of the rope, owing to its flattening from the action of the pull; but by the clip this is entirely avoided, as the pressure is equal on the sides and bottom of the groove. This secures the shape and smoothness of the rope."

In mountainous positions of considerable declivity, or where the ores have to be passed over gulches or rivers, or drawn from the bottom of large open-cut concavities, it will be also found convenient to stretch a chain or wire rope across, to serve as a

Cut 51.



guide for a traveling pulley; it should sag just enough to ease the strain, and to obtain a convenient angle for the transmission of a suspended car from the mine or excavation to the reduction works. For the economy of rope and draught, double wire rails and wagons may be worked by Fowler's clip pulley, or any other arrangement, either with or without power, for ascending or descending grades.

The following table will show the advantages, as regards strength, size, and lightness, of the iron wire rope over both chain and hemp rope, which have been generally used for such positions.

Breaking weight in tons.	DESCRIPTION.	Size in inches.	Weight per fathom. lbs.	Weight per fathom. oz.
	Wire rope..................	1 circumference.	1	0
4	Hempen rope.............	2 "	1	1
	Chain.........................	$\frac{1}{4}$ diameter.	3	0
	Wire rope..................	2 circumference.	3	8
8	Hempen rope.............	5 "	6	0
	Chain.........................	$\frac{1}{2}$ diameter.	16	0
	Wire rope..................	$2\frac{1}{2}$ circumference	5	8
12	Hempen rope.............	7 "	12	3
	Chain.........................	$\frac{11}{16}$ diameter.	27	0
	Wire rope..................	3 circumference.	7	8
16	Hempen rope.............	8 "	14	3
	Chain.........................	$\frac{13}{16}$ diameter.	36	0
	Wire rope..................	$3\frac{1}{2}$ circumference	10	0
20	Hempen rope.............	9 "	19	6
	Chain.........................	$\frac{29}{32}$ diameter.	46	0
	Wire rope..................	4 circumference.	14	0
24	Hempen rope.............	10 "	25	0
	Chain.........................	$\frac{31}{32}$ diameter.	53	0
	Wire rope..................	$4\frac{1}{2}$ circumference	18	0
30	Hempen rope.............	11 "	30	0
	Chain.........................	$1\frac{1}{16}$ diameter.	62	0
	Wire rope..................	5 circumference.	22	5
36	Hempen rope.............	$12\frac{1}{2}$ "	35	10
	Chain.........................	$1\frac{3}{16}$ diameter.	78	0
	Wire rope..................	$5\frac{1}{2}$ circumference	27	0
44	Hempen rope.............	14 "	41	10
	Chain.........................	$1\frac{5}{16}$ diameter.	96	0
	Wire rope..................	6 circumference.	34	0
54	Hempen rope.............	15 "	47	8
	Chain.........................	$1\frac{7}{16}$ diameter.	115	0

3. The battery should be self-feeding.*

* There is not an *exception* to this rule throughout Cornwall, England, even where labor is *very low;* so that no good reason can be shown why *expensive hands* should be paid for such unnecessary work.

4. Copper plates should be fixed within and without the battery; and when the outside plates are also electro-plated with silver, they may be amalgamated with greater facility, and will retain longer efficient affinity, etc., than when the naked copper plates are used.

5. Narrow transverse troughs of mercury, and double runs of blankets, should be placed at the ends of, and beyond, the plates; the former to catch both mercury and gold by direct union and amalgamation, and the latter to arrest, secrete, deposit, and concentrate escaping mercury and gold, as well as the heavy auriferous debris, which would otherwise pass away, for subsequent more suitable and efficient treatment. Beyond the runs of blankets, self-acting concentrators should be worked, and large catch or settling pits must be dammed or excavated, for still saving the heavy auriferous slimes, sulphurets, etc. Thus naturally concentrated, it may be re-treated by the company when a convenient time arrives for the purpose, or sub-let to others.

6. Where water-power, or cheap steam-power, and low rates of wages, can be taken advantage of, dry crushing and subsequent barrel amalgamation (or a small battery made expressly for supplying the wet pulp or "slough" directly into the barrels), and improved Chilian mills, have been rendered very beneficial for the working of low-grade quartz, as the extra length of time required is of less consequence, because more gold can be extracted from the same rock than when hurried through the agitated running waters and coarse screens of a battery.

7. The greatest possible economy of steam and engine friction should be secured, by having sufficient surplus power for the maximum beneficial expansion of steam, as used in vertical, long-stroke, single-acting, high pressure, condensing Cornish engines, as described in Chapter IV, Section IV, which are most economical. It too frequently happens that *deficiency of water*, *remote position*, and *bad roads*, demand a lighter and non-condensing machine, when the smaller, more wasteful, high pressure, horizontal puffing engine has to be used. The ordinary method for condensing spoils the water for battery amalgamation by rendering it greasy; but if Hall's

surface condensers are used, no such effect can be produced, but the water is improved for milling by being warmed.

Water-power should be used, when possible.

8. In many veins, it is very beneficial to assort the rock for quality, which should be done first within the mine, as it is handed back by the miners, and always after, when possible without much extra labor, by separating and keeping it separate, passing it through different mortars; for, as the low-grade quartz loses a greater ratio of the gold than the higher quality, it follows that any improvement of quality by such means must be more profitable; besides this advantage, it often occurs that one kind or quality should be worked in a very different manner to another; and some parts, being too poor, *should not be milled*, or certain loss will result instead of profit.

For an instance of argument, the costs of mining and reduction of auriferous quartz may be placed at $5, and an average of all the vein, without any selection, may be $5.50, and this would naturally yield a $0.50 profit on every such ton of rock, when forced through a battery in this extravagant manner; but an intelligent underground agent would, by daily examination of the mining and milling operations, discriminate the quality of different streaks, courses, or pockets, and by leaving proper directions for separation—or, rather, *keeping separate*—which requires little or no extra labor, he would thus, by increasing its average but say $2 per ton, not only increase the profits five-fold from the rock milled, but would also save the great expense of milling of the many tons of unprofitable rock.

In the mining and preparation of the base minerals, this economy from separation is invariably realized, or profits would seldom accrue from the millions of tons thus beneficiated.

Most of the copper ores of Cornwall, when first taken from the vein, did not average one per cent., being thus valueless, as nothing less than about three and a quarter per cent. can be sold at a profit; so that these ores are broken to suitable sizes, hand-separated, and machine-jigged, until they are so ridded of matrix that the mineral residue will produce as much more than the minimum saleable percentage as the extra cost of concentration dictates.

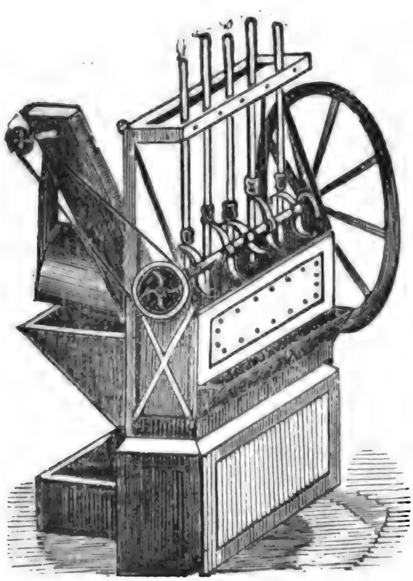
The average sales range but from five to six per cent.

Tin ores that contain but twelve pounds of oxide per ton may be there concentrated to absolute purity, and profitable results.

9. The general construction of parts and arrangement of driving gear of the pestles and mortars of Cornish and Australian batteries, are very different to those of California; and from these differences some of the greater economy may be derived. This has been, however, quite a matter of opinion; but, to some extent, there can be no doubt that each may be appropriate for certain peculiar circumstances; notwithstanding which, each country retains strong preference for their own style, which excludes the use of the other.

The Californian, when all the parts of each are made of iron, has a slight advantage in the weight; is of more refined mechanism; and as both the stems and pestles are circular, and lifted from under the side by a suitably curved eccentric cam, it is said to have the additional advantages (by twisting during its fall, and on the bottom at the moment of percussion) of *grinding*, and *more equal* wear.

Cut 52.



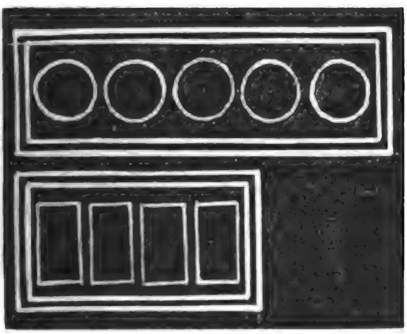
These "cams" or tappets are double-ended, and lift twice in a revolution of the small wrought-iron shaft, on which they are secured by keys at proper degrees of the circle, to lift the five pestles in suitable succession; which shaft (strange as it may appear to a Cornish reader) is driven by a belt, as shown by the accompanying cut.

10. The Cornish stamps are used in Australia; which have been fully described at pages 461, 462, and 463, in the chapter on such machinery as made in Cornwall.

These heads are lifted by tappets or "cams," which are

wedged into a long cylinder or barrel, five to the round. The engine-shaft is fixed in line, and goes round for round with this axle, at the rate of twelve revolutions per minute (which has been found the most economical speed for such an engine); and therefore each pestle falls sixty times per minute. The heads are not arranged for continual twist, but may be easily turned half-round occasionally, if found necessary to do so for more equal wear, which is, however, very seldom required. There can be no doubt that the heads are lifted at less expense of friction by this direct vertical action than by the rubbing, cycloidal motion of the Californian cam; whilst far more important effects are produced in much less space by the oblong mortar-filling heads than by the circular pestles; this is best seen by the accompanying illustration, that is drawn to scale so as to show area against area, with comparative cover, and length against length, better than all the words in the language can express.

Cut 53.



11. Concentration, and subsequent treatment for roasting off the deleterious volatile element, and extraction of the gold and silver by proximate humid or fire chlorination, and ultimate pan and barrel amalgamation, should be always resorted to when practical, for the beneficial realization of its precious contents.

12. All available cheap means should be resorted to, as explained in Chapters VI and VII, Section IV, for the retention and separation of the heavy from the light debris, as it passes from the battery to the catch-pits; and this being first done by the company, the pits may be sub-let to an intelligent and honest workman, at a percentage value, for mutual advantage.

THE MILLING OF GOLD BY BATTERY, WITH WATER AND MERCURY.

This is the most direct and ready method for the extraction

of gold from quartz, when it is in what is called "free condition," or metallic, visible, and bright; but when enclosed in the sulphurets of copper, iron, or lead, it cannot be thus extracted without effectual preparatory roasting. In some instances, even this will fail to accomplish sufficiently perfect results, when the *free portions* may be extracted during its pulverization, with water and loose mercury, in battery and quicksilvered copper plates, and with riffles, shaking tables, etc.; the heavy residue of auriferous sulphurets may be concentrated by flumes, buddles, revolving or fixed blankets, machine frames, or other concentrators, and then amalgamated, after oxidation by roasting, or by long exposure (in the extensive layers) to atmospheric re-action, in close barrels, arrastras, Chilian mills, or ironpans, by Plattner's method of chloridation, or other chemical means.

A Cornish or Californian battery may be supplied with quartz by hand, or in a self-feeding manner, and sufficiently pulverized that it shall pass through an iron wire gauze or perforated front screen plate, having from thirty to fifty holes to the inch, which is somewhat dependent on the fineness of the gold and hardness of the quartz.*

The copper plates are generally placed both within and without the battery, and should be electro-plated with silver, so that the quicksilver shall readily adhere to the cleaner and more attractive silver surface.

When copper plates are used inside the mortars (which, however, realize but questionable advantage), they are generally made to flare at an angle of about 30° towards the front and back sides of the battery; and the feed-plate should overhang the sheet of copper, so that it may not be damaged by the falling charge.

The perforated screens of iron which front the mortars should be fixed in frames, so that they can be readily slidden or unscrewed from the front, for better access to the interior. The outside copper plates will receive and retain the coating of mercury much better when electro-plated with silver than when the naked copper is used.

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* Perforated plates are not always used in Cornwall; but the impalpable debris is washed or "flushed" out by succeeding waves over ascending launders, which then discharge into ordinary buddle strips or flumes.

From three to six plates are used, which are placed in as many steps or terraces, as long as the breadth of the mortars, and from six to twelve inches in width.

These plates should be of such declivity that the escaping debris may loiter in passage over the plates and transverse intervening pools of mercury, which are thus angled for the arrestation of gold, and the globules of amalgam or mercury. Shaking troughs of mercury, and other devices still beyond all these, have been also used to advantage in Australia.

Plates may be more readily amalgamated when perfectly clean, which may be easily accomplished by rubbing them with a mop moistened with a small quantity of dilute nitric acid (five or six parts of water to one of the acid), just before the mercury is applied. They may be also cleaned with wood ashes, or other grinding powder, by rubbing.

The mercury may be cleansed and prepared for better action, both for plates and amalgamation, in different ways.

1. It may be purified by being volatilized in a heated iron retort, and condensed into metal by passage through a small cold pipe. Retorts are made and sold for this express purpose; but they may be extemporized by screwing a condensing syphon pipe into the iron bottle in which the mercury is supplied, and treating as before. The heat should be gradually applied, and the long leg of the syphon may descend into cold water, for condensation. The condensed mercury should be then shaken with dilute nitric acid, and be kept at about 130° of heat for some hours: now add water and a piece of clean copper, to precipitate the mercury from the solution.

2. It may be partially cleansed by water-washing, and straining through buckskin; the former passes off all the lighter deleterious mechanical debris, and the latter removes nearly all of the amalgamated metals by filtration.

3. Much foreign matter may be removed in solution, by a mixture of two parts of water and one part of nitric acid. The solution may be poured off, the mercury well washed in clear water, and its affinity still further sharpened by a small quantity of a water-solution of cyanide of potassium.

4. A small piece of metallic zinc may be added to *well-washed, strained* mercury, which greatly increases its cohesion

and amalgamating qualities. If the mercury is warmed in a suitable kettle, the zinc will be amalgamated therewith much more readily and effectually than when cold.

5. *By my patented process*, as advertised in card.

6. *Sodium amalgam.*—Mr. Thomas Bell, of England, who appears to have thoroughly examined this subject, says:

"1. When a little of the sodium amalgam was added to the ordinary mercury, the affinity of the latter for gold was greatly increased; so that when dipped into it, they were instantly covered with mercury to which no sodium had been added. Amalgamation was very slow, and difficult to obtain.

"2. Floured mercury immediately run together into a single globule, on the addition of a little sodium amalgam.

"3. When iron pyrites (bi-sulphuret of iron), magnetic iron pyrites (sulphuret of iron), or copper pyrites (sulphuret of copper and iron), were triturated with sodium amalgam, the pyrites were decomposed; and on the addition of water, a black precipitate of sulphuret of iron was obtained.

"4. Triturated with sodium amalgam—*a*, Arsenical pyrites were decomposed, and arsenic amalgam formed; *b*, Galena (sulphuret of lead) was decomposed, and lead amalgam formed; *c*, Blende (sulphuret of zinc) was decomposed, and zinc amalgam formed; *d*, Litharge (oxide of lead) and white lead (carbonate of lead) was decomposed, and lead amalgam formed.

"From these experiments, it appears that sodium amalgam has an energetic action upon both the oxides and sulphurets, reducing both; and as the sickening and flouring of mercury is supposed to be due to the formation of the protoxide and the sulphuret of mercury, its beneficial effect appears to lie in the reduction of these; but if added in excess, it will, after effecting this operation, attack the ores of the base metals, and with many of them form amalgams. The mercury then becomes loaded with the base metals, and its action upon silver and gold is greatly reduced. Where arsenical pyrites is contained in the ore treated, the arsenic amalgam formed by the action of the excess of sodium floats on the surface of the mercury, and prevents the gold from coming in contact with it. It is thus seen that only sufficient sodium should be added to reduce any mineralized mercury, and to keep it in an efficient state The quantity added, and the duration of its effect, will vary with different kinds of ore treated, and it is well known that some minerals sicken and flour the mercury much more quickly than others. The whole question of the fouling of mercury, when used for amalgamation, requires a much more careful chemical examination than it has yet received, and it is a matter of great importance to miners that the attention of so able a chemist as Mr. Crooke has been directed to the subject."

It will be seen from the above examinations that sodium amalgam is very effective; indeed, for some base ores, too much so, for all are amalgamated that ever form such union with mercury, and great judgment is therefore necessary, so as to ascertain when it should or should not be used.

There can be no doubt of its being, in some cases, beneficial; whilst it is of general benefit for the more rapid and effectual amalgamation of copper plates.

About one and a half per cent. of the sodium amalgam is mixed with ordinary mercury, which is then delivered to the mortars of the battery in the usual manner every half-hour,

in quantities that vary according to the rock (about one-fourth of an ounce will be generally sufficient), and which can be ascertained by the appearance of the outside plates.

If they are dry, more mercury may be added, until the faces show a semi-liquid appearance. If small globules pass away in the tailings, and the plates are quite liquid, less should be supplied.

The most certain, and by far the better way, is to tie a piece of strong cloth firmly on to the neck of the bottle, so that the mercury may be filtered through in smaller and more certain quantities.

If the outside plates expose evidence of natural repulsion for amalgamation, they may be revived, for affinity, by a dash of cyanide of potassium, and application of one of the superior alloys of sodium or zinc amalgams, or sometimes by nitrate of mercury, which copper precipitates.

The zinc amalgam is also much superior to ordinary mercury, for it has greater activity, and a peculiarly strong affinity for silver and gold, but does not so readily amalgamate with the base metals; so that where the sodium should not be used, this can be brought into much more effectual service.

Although it is sometimes beneficial to use mercury in the battery, as well as on the outside plates; at other times, with gold, which amalgamates more readily, it appears to be unnecessary: this should, however, be decided by actual and individual trials.

For some kinds of auriferous quartz, it is also very advantageous to supply a diluted solution of cyanide of potassium, drop by drop, from suitable jars placed over each mortar, which sharpens the action of the mercury for union with the gold, both on the interior and exterior copper plates.

THE MILLING OF GOLD AND SILVER ROCK IN DRY STATE, FOR SUBSEQUENT ROASTING AND FINAL TREATMENTS.

This is simply the pulverization of the quartz from the rock-breaker or hand sledge, without any water, as in an ordinary mortar, so that the impalpable powder shall pass by way of close pipes from the mortars to suitable receivers, for being roasted, panned, barrelled, chlorinized, or dissolved and

precipitated by other chemical methods. Cut 52 shows such a battery. In this pulverization, the whole is generally made to pass through a screen of wire gauze having forty holes to the lineal inch, or 1600 to the square inch.

THE AMALGAMATION OF GOLD IN IRON PANS.

This is merely a continuation from the treatment in battery, as last described. The pulverized ore, that may contain some unamalgamated free gold besides that which is either partially glazed over, or securely imprisoned in sulphurets, being caught in large catch-troughs, is now to be further ground in iron pans, with mercury and sufficient water to form a mobile pulp, in which the mercury circulates for the more thorough amalgamation of the gold, as it is released and brightened by friction, for actual contact and effectual affinity.

During the *charging of the mercury*, and until you can observe it in *proper circulation* amidst the pulp, which should be carefully brought to proper consistency for this purpose, the muller or grinders should be slightly elevated from contact with the bottom, so that the mercury may not become "floured," or too much divided into minute particles, as it cannot be very readily recovered into total union as before, and a loss of both mercury and gold would be the result.

If this should occur, a very little of the sodium amalgam may be added for its re-union, as this appears to be its most remarkable power.

The charge usually treated for the largest and best pans, of four and a half feet in diameter, varies from 2000 pounds to 2500 pounds, which may have from one hundred and forty to one hundred and eighty pounds of mercury.

The speed of the mullers of such a pan may be from forty to fifty revolutions per minute.

The time given for amalgamation is generally a little less than four hours, so that six runs may be made in the twenty-four hours.

The charge is then run off with excess of water into separate stirring vessels, for settling the mercury; and the still auriferous sulphurets are caught and concentrated, for beneficiation by chloridation.

The mercury is now recovered for re charging as before; it need not be strained more than about once a week for its amalgam of gold.

Such a pan will pass through from four to five tons per day, and the number of pans should be equal to the capacity of the battery. The whole arrangement may be seen in the large cut of Californian battery, pans, settlers, etc., at the end of this work.

For *sulphurets and floating gold*, this is ineffectual, whilst it is too expensive for low-grade rock; so that unless silver ore is also present in notable and profitable quantity, it will seldom be beneficial, if proper precautions be taken for realization of the available gold in battery, and for retention and concentration of the heavier debris, for ultimate chloridation and precipitation of metallic gold by Plattner's process.

MILLING OF GOLD AND SILVER IN IRON PANS.

It has been previously stated, and should be always remembered, that no ore can be worked with certainty until its constituents are ascertained, so as to know if it should be roasted or milled in direct manner; chloridized or smelted.

Having decided that it must be milled, either before or after roasting, by battery and iron pans, for both silver and gold, the following may serve to guide you against the omission of certain requisites, and the commission of serious errors.

1. Chemists are not thoroughly acquainted with the actions and re-actions which transpire in pans; but this much is certain, that thorough decomposition is not produced in a humid chemical manner.

2. It is a well substantiated fact that the heat created by friction, during the pressure of grinding, causes an electrical action, which the iron of the pan, the mercury, and liquor, increases by electro-galvanism; so that these may be the effective causes for amalgamation.

3. It is more important that the mercury be kept in clean active condition, by retorting, straining, and the aid of clean water and suitable chemicals, as described under "Gold" and in the comparative and collective treatments of Califor-

nia and Australia, than that any chemicals should be added for reducing the sulphuret ores, by any such direct means.

4. In the amalgamation of the *sulphuret of silver* ores, the most experienced men have declared that nothing has been gained by the use of expensive and strong chemicals; but this cannot be true for the more common and cheaper salt, in the hot solutions of which silver is soluble.

5. When chemicals are used, care should be taken that their elements are calculated for producing some especial effect, and that they will not act on each other for useless neutralization, as acids with alkalies, alkaline earths, etc.

6. If the alkaline earths are present, it will be better, for the reasons under the last heading, to treat both the mercury and the ore with one of the alkaline or neutral receipts, or at least by such as will not act on these matrices.

7. The chemical changes which are produced by roasting are more direct, certain, effectual, and economical, than any yet attained by humid methods.

8. The chemicals used should also be conformable to the condition that has been produced by roasting; for if the silver is sought for by hot chloridation and amalgamation, the base metal chlorides will, by being soluble, have actually supplied some of the chemicals in excess; also, if the roasting has been sufficiently prolonged for the formation of the soluble sulphate of silver, the pan will require salt for better amalgamation; and if the base minerals have been oxidized, they will unite with acids so readily as to completely nullify any other useful effects which might have been intended.

9. There are several iron amalgamating pans of the different inventors, illustrated at the end of this work; but to attempt to say which is best will be worse than pillowing on a hornet's nest; *judge for yourselves.*

10. In selecting pans, you may, however, bear in mind that the best grinder is not necessarily the best amalgamator, and therefore a mean between the two effects will be most desirable. It is also necessary that convenient screw action should be provided for raising the grinding shoes from the bottom, when advisable to do so. For treating silver, the bottom should be made hollow, for the admission of steam.

11. Separate settlers should accompany pans, as they save time, and perform the work much better.

12. Gold can be amalgamated just as promptly and completely in cold as in hot water; chemicals are only valuable for cleaning and increasing the activity of mercury, as previously explained; it is otherwise amalgamated *in pans*, in similar manner to silver.

13. Silver, on the contrary, can be amalgamated much more easily and effectually in hot solutions than in cold; especially when salt and the other soluble chlorides are used to dissolve or precipitate.

14. *Free g ld can be beneficially amalgamated in battery*, without pans, barrels, arrastras, or Chilian mills, by sufficient extent of surface of amalgamated plates, etc., etc.; so that the expensive pan process is more beneficial for the founder than the miner.

15. When silver is also present in remunerative quantities, it should have the *double treatments of battery, pan, etc.*

16. Some of the silver ores are so friable that they will pass off in the agitated waters of a battery to an alarming extent; so that either dry crushing should be resorted to, or the battery be worked with but sufficient water for the supplying of the whole of the water and pulverized ore to large catch-pits for barrels or pans, to obtain greater security and much more complete amalgamation.

THE MILLING AND AMALGAMATION OF SILVER ORES BY BATTERY AND PAN.

I am informed that Mr. Almarin B. Paul first used iron pans for the amalgamation of silver ores pulverized by battery, at the "Devil's Gate Mill," near Silver City, Nevada.

The twenty-four stamp mill and its sixteen pans were ordered on the seventh day of June, 1860, and started on the morning of the eleventh day of August of the same year.

At that time, it was used merely as a more convenient arrastra, and little difference prevailed in the *chemical treatment* of the ores; although it was made to travel, grind, and amalgamate much faster, and thereby force more silver from the rock in the same time, regardless of what percentage was left in the tailings.

There is still great waste of silver (amounting to some $20 per ton in the tailings), after the best treatment by modern pans; so that, with all the experience, these more expeditious pans must be placed behind barrels, and but just on equality with improved Chilian mills and good arrastras, both as regards cost for extraction, and the percentage of silver obtained.

When the ores require to be roasted and chlorinized, for more effectual amalgamation in pans, they must be necessitously crushed in the battery in a dry condition; and it is frequently better to crush dry in other instances, for many silver ores are so friable that they will pass away from the battery by floatation, as a highly argentiferous impalpable powder, and occasion very considerable loss.

In this connection, it must be remembered that all the silver ores are remarkably soft, and will consequently become finely powdered very much sooner than their quartzose matrix. These things have not been sufficiently regarded by millers, and the total credit has gone to roasting, when the accompanying and *necessary dry crushing* should have at least had a considerable share of the resulting difference over the direct wet treatment of raw ores.

The ore is first pulverized in the battery, either dry or wet, as for the battery amalgamation of gold, but not necessarily to such fine division; as the *soft and coarser* ores are more readily ground to unite with mercury than is the case for gold, where the *hard quartz* has to be so finely ground that the *most minute specks* of gold may be reached by the mercury.

Whatever pan you may select, it should be very large—say six feet in diameter—as much more can be treated at about the same expense of time and money. It should be made with a hollow bottom, for steam-heating, and have a convenient means for raising the grinders as often as may be desirable from the bottom, for better initial dissemination of unfloured mercury, and subsequent settling, before it is run off into separate stirring settlers.

The water is first charged, then the ore, just so that the mass of pulp shall roll over and over in its annular spiral route, in a free and easy manner, neither so wet that the mercury, which is now charged, shall be at the bottom of the

pan, nor so dry that the grinders shall either force passage, or carry the pulp forward with stubborn roll, or *en masse.*

The quantity of the charges of ore and mercury must be governed by the capacity of the pan, a six feet pan managing about six hundred pounds of ore, and requiring about one-eighth its weight of mercury, *prepared as for gold.*

The chemicals that were used in 1863, for working the gray sulphuret ores of the Comstock vein, as recorded by Mr. Küstel, appear more varied than accurate or useful, which may be seen from the following list. The quantities are said to be equal to from 250 to 500 ounces of silver, and sufficient for a ton of ore.

"*a.* Chloride of copper, 13 pounds; common salt, 60 pounds

b. Chloride of iron, 13 pounds.

c. Sulphate of iron, 1 pound; sulphate of copper, 8 pounds; common salt, 80 pounds.

d. Sulphuric acid, 3 pounds; sulphate of copper, 2 pounds; salt, 15 pounds.

e. Sulphuric acid, 2 pounds; alum, 2 pounds; sulphate of copper, 1½ pounds.

f. Sulphate of copper, 1.2 pounds; sulphate of iron, 1 pound; sal ammoniac, 0.8 pound; common salt, 2 pounds.

g. Alum, 1½ pounds; sulphate of copper, 1½ pounds; salt, 40 pounds.

h. Muriatic acid, 30 ounces; peroxide of manganese, 8 ounces; blue vitriol, 10 ounces; green vitriol, 10 ounces.

i. Common salt, 15 pounds; nitric acid, 1 to 2 pounds; sulphate of iron, 1 to 2 pounds.

k. Common salt, 25 pounds; blue vitriol, 2 pounds; catechu, 2 pounds."

It is clearly shown, by comparison, that the above receipts were governed more by random notions than chemical inductions, as more particularly displayed under the letters *c*, *d*, and *f*, and in the variations of the more generally recognized salt; the chemical practice having been once started, each vied with the other for superior process receipts, and none stopped for sober comparative trial with the non-chemical pan and mercury.

It now appears that if efficient large pans be driven at a lively speed, warmed by steam in hollow bottoms to about 160° of heat, and supplied with mercury in good condition for affinity, that *friction, heat, properly prepared mercury, and thorough circulation of the pulp*, will successfully compete with any one of the chemical receipts.

It is therefore an important question whether these supposed excellences, from all except salt and soluble chlorides, did not arise from their direct action on the mercury, during this short process, rather than on the ore itself?

If chemicals are used, their much better application may be by the preliminary, more certain, but slower action of a modified Patio process, on large quantities without mercury, for completion in pans with mercury.

In the supposed best receipts, *sulphate of copper* is present, which would be precipitated by the *iron* pan, during the grinding of sulphuret ores, as metallic copper; thus it would, by uniting with mercury, increase its affinity and galvanic action for superior amalgamation.

If this is the most efficient re-action, the sulphate of copper or the metallic copper had better be introduced to the mercury itself, by direct amalgamation in the pan or preparatory bottle.

Copper strips could be placed on the grinders, for removal, when necessary to do so.

The cleansing of mercury has been already described under "Gold," and this matter of alloy discussed under the "Zinc and Sodium Amalgams," at pages 527, 528.

As zinc has a more superior affinity for silver and mercury than for the other associated metals and minerals, and causes a still greater galvanic action, there can be but little doubt that amalgamation will be much more readily attained by mercury thus prepared as there directed, than when it is not so charged.

Sodium amalgam is also most valuable for concentration of "floured" mercury.

As it is so evident that mercury must be in good condition, it should be frequently examined during the grinding, and when fouled to sluggish affinity, it may be found very advantageous to withdraw it, and supply active mercury for the more effectual completion of the run.

Common salt, however, is found to be beneficial, for reasons given, and being cheap, it is economically available.

The mechanical manipulation of the ore is very simple; but it is necessary that care should be taken as to speed of pans, and proper circulation of the pulp, which is generally carried too much to the periphery by centrifugal force, unless well provided with opposing mechanical means for returning it to the centre; large pans have a great advantage in this respect, as well as in the extra quantity that can be reduced in the same time, and it is probable that annular pans of much larger size will be found still more advantageous.

The heat produced from steam and grinding dries the pulp, and care should be taken that the water is added in a regular manner, or the pulp will be, for the greater part of the time, either too wet or too dry.

The time of grinding is so arranged that a similar number of charges shall be completed in the twenty-four hours, and, to this end, a little less than four hours are given. Separate stirring pans settle the last runs, so that the panning is continual. The mercury is only occasionally strained, according to the richness of the ore, or presence of base amalgam.

At the proper time, when it begins to show signs of thickening, it must be drawn off, after completion of the charge and discharge of the pulp, by removing the bottom plug, washed thoroughly clean, and the mercury then strained through a conical bag, which is made of strong canvas, so as to leave the thick amalgam behind on the filter. To remove the last trace of fluid mercury, some little pressure may be applied on the mass.

This amalgam may be retorted, for the recovery of mercury and realization of the gold and silver, by an apparatus which is very simple, and just similar to a retort for making coal gas.

The retort is made of cast-iron, of various shapes, but mostly cylindrical, or of an elongated egg-shape. It has a rib on each external side, running its whole length, so that it may be laid on the side walls of a fire-place, in such a way that two flues may be formed, continuing from the fire-place back, to return over these ribs, for the equalization of heat.

It is generally made from three to four feet long, and of some ten or eleven inches in diameter, having a stopper or

removable door at the fire-end, and a syphon pipe of some five or six feet long at the other end; this pipe leaves from the top, and is terminated by an expanded funnel-mouth, which descends about an inch into the water of a suitable iron tank, that receives the condensed mercury.

If the fuel is wood, the fire-place may extend the whole length; but if charcoal, stone-coal, or coke is used, about two feet six inches will be found sufficient.

The cones of amalgam may be now broken in small pieces, and placed within the lower half of the retort, which had been previously luted with a thin coat of finely pulverized wood ash, to prevent adherence. The end must be now stopped perfectly tight, by the screwing or keying on of the door, over a joint of finely pulverized and moistened ash.

The fire may be kindled, and the retort brought very gradually to a low red and red heat, when the volatilized mercury is condensed in the vertical part of the syphon pipe, which is enclosed by another larger pipe, through which cold water flows continually, after the manner of Liebig's condenser, for still more speedy and effectual condensation.

The success of this operation depends on the gradual increase of temperature to low red, which requires some three or four hours, when it should be increased to just red, but no higher, for about three hours more, until no mercury falls into the tank.

The fire is now removed, or allowed to burn down; and after the retort becomes *quite cold*, the charge of metallic sponge is removed for further purification, as directed under the past headings 26 and 27 in the chapter for "Assaying of Gold and Silver," at pages 284 and 285, and under the future Chapter IV of this Section, on "Smelting."

AMALGAMATING IN COPPER—BOTTOMED PANS

Is principally used in South America, for rich rock, which contains either the chloride, bromide, and iodide or metallic silver.

If the native ore is in any other form, it must be brought to one of these conditions by artificial means, such as roasting at high temperature for reduction to metal, or with salt for chloridation.

The ores are first pulverized in dry condition, by the most convenient means, to an impalpable powder, which is then placed in copper-bottomed pans or kettles, with about twice its volume of water, some ten per cent. of salt, and as much mercury as there is silver in the ore.

This is well stirred, and boiled for some five or six hours, during which an occasional examination is made of the mercury, so as to see by its fluidity or pastiness whether more mercury should, or should not, be added, for amalgamation of the still remaining silver.

It is said that the loss of mercury about equals the quantity of silver gained, which is less than that from amalgamation in heaps.

This is a very simple means for reduction of silver ores; and *where wood is plentiful, and roasting and chloridation must be accomplished even for ordinary amalgamation*, it appears to deserve more attention than it has ever had given to it.

It requires but trifling power; much less outlay for purchase, carriage, erection, and running expenses; and but little skill for manipulation: any number of kettles may be used, either under cover or in the open air, which may be placed on a terrace in the side of a hill, so that the fires may communicate with one transverse flue, and thence to another diagonal ascending flue, or elevated chimney, of sufficient size and height for creating draught for the number of fires required.

AMALGAMATING IN ARRASTRAS.

This, the most primitive means for mechanical amalgamation, has, and still will have, many advantages.

1. It will, under good supervision, yield fair results.

2. It is the cheapest, easiest, and most convenient means for the poor man.

3. It can be worked by horses or mules, where feed can be obtained.

4. It is both battery and pan.

5. It can be made on the spot, and requires no expensive carriage.

6. It requires no expensive covering.

7. It has no costly wear and tear.

8. There is not much difficulty in its management.
9. A small quantity of mercury is required for working.
10. No chemicals nor fires are needed.

To arrange this apparatus for work, a kind of pan is made, by either cutting out from the natural bed-rock a circular bottom of about fourteen feet diameter, or by inlaying segments of cemented stone to a similar size and shape, and bordering it with a two feet high water-tight fence of wood. In the centre of this stone bottom a hole is drilled; in this a vertical axle is placed, the top end of which is also made to work in a suitable guide that is attached to a transverse beam, in a somewhat similar manner to that for the horse-whim shown at page 368.

On this central vertical axle is firmly attached the horse-arm, which extends sufficiently over the edge of the pan, on the one end, to give leverage and easy travel for the horses or mules, and reaches but to the edge of the pan on the other side; another bar is also secured in similar manner to lie at right-angles with this, just across the pan. These arms are notched, for the attachment of chains, ropes, or cow-hides, which draw one, two, or four flat and hard stones, of about three hundred pounds each, around the ring, so that their heads are suspended and drawn the more easily over, whilst the full weight of their tail-ends will rub heavily upon, and grind the ore into pulp.

The quartz is first broken to the size of a chestnut downwards; a little water and about two hundred pounds of this ore is first distributed over the bed whilst the machine is in motion, and as soon as this has settled down to a reduced size of peas, two hundred pounds more may be added and ground to a pulpy consistence with a proper amount of water, which generally requires from four to five hours for hard quartz.

Mercury must now be scattered over the whole surface, from a bottle that is muffled with a coarse linen rag, so that every ounce of gold in the rock shall have one and a quarter ounce of mercury, and the grinding continued for two hours longer, care being taken that the pulp is of the proper moisture for the circulation of small globules of the mercury through the mass, for the effectual amalgamation of the gold. Before the time has expired, about two ounces of the pulp

should be examined in a horn spoon, to see if any free gold still remains unamalgamated; if so, more mercury must be added; and if not, an excess of water may be supplied, and a slow motion given, so that the amalgam may be thereby allowed freedom and time for settling to the bottom. In about from twenty to thirty minutes this will be accomplished, when all the pulp and water is drained off through the appropriate channel for that purpose, and other charges of ore are treated upon the same amalgam, until it is considered advisable to clean up for realization.

In rough and badly jointed bottoms, this is allowed to remain for some three or four weeks, as the mercury has to be dug up from the joints, and the work must be renewed; but in the better jointed, cemented arrastras, it may be cleaned oftener, as the bottom is more enduring, and remains as good as ever it was.

The amalgam thus obtained may be treated as described at page 537, or by the Mexican method, under an iron bell, which is supported over water, and heated by a covering of burning wood or charcoal.

The arrastra is a good amalgamator, but an indifferent, or at least an expensive grinder. Therefore the question naturally arises whether it should not be more frequently used as an amalgamating auxiliary, after finer dry crushing by rock-breaker or battery?

AMALGAMATION BY CHILIAN MILL.

This is worked and arranged somewhat similar to the arrastra; and for economical grinding power it may be considered its superior, as much less power is required to roll a large disk than to slide heavy flat stones.

The rolling disks are propelled by horse, water, or steam power, on a somewhat similar flat bottom of stone, just like the cement and lime grinders used by masons; sometimes two such cheese-shaped stones are worked on each side of the centre, the one traversing a less radius than the other, to more effectually cover the pan. As the inner parts of the stones are as large in diameter, and make as many revolutions, as the outside parts, and have to travel different annular distances, it follows that a twisting or grinding action works on the ore, as well as that of crushing.

In the most improved mills, iron pans are used, which, when costless water-power can be obtained, and sufficient time can be given, realizes more economical results and beneficial returns of metal. The general advantages obtained for poor miners, modes of charging, working, and discharging, differ but little from those for amalgamation by arrastra; so that it also becomes most subservient for the earlier testings of veins, and for interior uses in far-distant, inaccessible mountainous regions.

ARTIFICIAL STONE ARRASTRAS AND CHILIAN MILLS.

It appears to me that the patented, and justly celebrated, London and Paris Exhibition medalled, artificial stone of Ransome, as just exhibited at the Eighth Industrial Fair of this city, is superlatively well adapted for the formation of arrastra and Chilian mill pans; for hard sand can be obtained almost anywhere, and with some of the patented preparation of cement for uniting such, the desired shape can be obtained with the greatest facility, so that these mills may be rendered much more available than they are now.

It could be also used for making reservoirs for *at least some* of the slow preparatory (non-destructive) chemical treatments that should more frequently precede amalgamation by pans.

AMALGAMATION IN CLOSE REVOLVING BARRELS.

This is in many cases the very best means for obtaining gold and silver by amalgamation, where the previously pulverized raw or roasted ore is enclosed in a sufficient number of revolving barrels, with the other necessary ingredients.

1. *The ore should be crushed in perfectly dry state in a battery, to pass out through its screen of not less than forty to the lineal inch, into reception boxes, for barrelling process.*

2. It should be roasted, when necessary, or chlorinized, as previously described under "Furnace Chloridation;" and when excesses of base metal soluble chlorides are formed, they should be volatilized, or be changed by the addition of lime, to other insoluble conditions, as previously advised.

3. Each barrel may be now charged with 1000 pounds of ore, and sufficient water—about three hundred pounds—to

render it thoroughly mobile, and two hundred pounds of scrap iron; then stopped closely by its screw bung, and run for three hours, some fifteen turns per minute, so as to dissolve the soluble salts formed during roasting, and reduce the general debris, into a thin pulp.

4. The charge of mercury must now be added (say two hundred .pounds); and then, after another run of about eighteen hours, at twenty revolutions per minute, water is added to half fill the vessel, and a speed of eight rounds per minute is given for two hours, so as to concentrate the amalgam to a molten state, when it is drawn off through an especial small hole in the bung.

5. The pulp is now run off into a large settler, similar to those for pan amalgamation, and then discharged into long riffled buddle flumes, and thence over blankets into catch-pits, for arrestation of as much mercury as possible.

6. The amalgam may be now strained and retorted, and the precious metals realized by fluxed smelting, as before described for other amalgams, at page 537.

These barrels or casks are made of wood, are strongly bound with iron, and supplied with end axles, on one of which the driving toothed-wheel is placed.

As many are used as the quantity of the ore demands, and if possible they should be driven by cheap water-power. A funnel or hopper is placed above each, which is provided with a wood pipe and canvas nozzle, for feeding the barrels through their bung-holes. They are also discharged through these bung-holes, by inversion, into large underlying **V** launders, which serve to convey the pulp into settlers, as described.

One driving shaft is sufficient, which is extended the whole length of the row, having pinions for each barrel: the barrels are supported by, and roll between, wood posts. The water is also supplied by suitable and convenient pipes or launders.

In the State of Nevada, where competent labor can be now obtained at $3.50 per day, the total cost may be placed at from $17 to $23 per ton, dependent on the nature of the ore; the *actual barrel amalgamation* costs but about $2.80 under steam power; by far the greater portion is therefore required

for defraying the heavy expenses for dry pulverization, roasting, chlorinizing, etc.

The sulphuret silver ores of the Comstock vein, when amalgamated by barrel process, will yield, under ordinary practice, some eighty-eight per cent. of the actual value contained. By careful examination of the ore, consequent economy of materials, perfect chlorinization, excess of iron and mercury, a much closer result may, however, be obtained; even to ninety-three per cent.

The best results realized by pan amalgamation of similar ores will never exceed eighty, and seldom that of seventy-five per cent.; whilst the general average will be about sixty-six.

The custom mills charge even now at the minimum rate of $12 per ton; and it will appear by the following extract from an annual statement issued by the Crown Point Gold and Silver Mining Company, that but a small margin is allowed for direct profit.

"The ore statement for the past year shows 25,833 tons worked, yielding $845,627, or an average of about $34 per ton, as follows:

	Tons.	Average.	Amount.
Rhode Island Mill	17,685	$30.93	$546,959
Outside mills	8,148	36.54	297,641
Assay grains			1,027
Totals	25,833	$33.73	$845,627

"The average cost of working the ore for the past year was $11.66, and for mining $9.80, making a total cost of $21.46 per ton."

In cases where the ores *must be roasted* for *either* process, the *barrels are therefore better*, as they obtain much more metal than pans, and at less cost.

AMALGAMATION OF SILVER IN HEAPS, BY THE PATIO PROCESS.

As this subject cannot be very well completed without giving some account of this apparently dubious, but sometimes valuable process, I have (not having been familiar with it) extracted from Dr. R. H. Lamborn's "Metallurgy of Silver and Lead" the following general description, and comparative table of costs, for treatments by barrel, patio, and smelting, which will be both interesting and instructive.

This process can be used to advantage in hot countries only; it will not extract silver from argentiferous galena, nor is it adapted for the amalgamation of gold.

"The American system of amalgamation differs from the European in requiring for its accomplishment but little machinery, in being more wasteful of quicksilver, and in necessitating a longer time for carrying out its various processes. It is also different in the nature of the chemical re-actions upon which it rests, as will be observed in the following description. It is very largely in use in Mexico and Peru, and is particularly suited for those remote mountain districts where fuel and motive power are difficult to obtain.

"The silver exists in these countries in veins running through crystalline and Plutonic rocks, and in a native state, or combined with chlorine, bromine, iodine, sulphur, antimony, and arsenic. In the greater number of veins, the portions nearest the surface have been much changed by the influence of the atmosphere and the surface water. These parts usually contain the precious metal in an uncombined condition, or as a chloride or iodide distributed regularly in a gangue of quartz or oxide of iron. At a lower level, the compounds of sulphur and arsenic are more generally found.

"In the preparation of the minerals for metallurgic treatment, it is sought to separate the compounds of antimony, sulphur, and arsenic, from those containing the silver in a native state, or combined with chlorine, bromine, or iodine. The former minerals constitute what are known as *negros*, and the latter are denominated *coloradoes*, and the metallurgic treatment to which the two should be subjected is quite different.

"The average richness of the ores treated in Mexico is about 0.25 per cent.

"The *coloradoes* are usually well sorted by hand, at the mouth of the mine, and in a few instances submitted to the usual concentration by washing. The sorted ore is then stamped by machinery put in motion by mules or water-power, and then ground fine in peculiar native mills known as *arrastras*, which consist of a circular bed of hard stone, smoothly dressed and surrounded by a wooden tub. In the centre a pivot sustains four arms, to which are attached the same number of *mullers* or heavy flat stones, by which the grinding is effected These stones are made to move around upon the hard circular bed, by the power of mules attached to the extension of two of the arms. The ore from the stamping mills is mixed with water, and treated in this apparatus until a very fine powder is produced.

"The ground ore is now deposited in basins of mason-work, and allowed to remain until a greater part of the water is evaporated. It is then transported to the court of the *hacienda*, as the amalgamating establishment is generally called, and there thrown into a heap usually ten inches high, and depending in size upon the amount of ore to be treated. When, for instance, 50 tons are to be worked, its diameter will be about 50 feet.

"Upon the top of this bed of ore is thrown an even layer of common salt, amounting in quantity to about two per cent. of the ore. The salt is allowed to dissolve gradually, and in order to produce a homogeneous mixture, the heap is turned with the shovel, and horses and mules are driven around upon it for several hours. After this treatment, it remains untouched for about a day, and then the attendants proceed to add the *magistral*.

"This important agent in the American amalgamation is made by roasting at a low temperature the sulphide of iron and copper. When of a good quality, it should contain about twenty per cent. of the sulphates of these two metals.

"From one to two per cent. of the *magistral* is mixed with the ore, in the same manner as the salt, and the heap well stirred by driving mules upon it; or where the absence of food for animals makes their support too expensive, the workmen themselves walk round and round upon the soft mass.

"When the mixture is complete, the first addition of mercury is made. The metal is added, to the amount of about four times the weight of silver shown by assays, or estimated by the directors to be present in the mass. It is thrown evenly over the surface by squeezing it from a leather or canvas bag. After this addition, a *repaso*, or tramping by mules, horses, or men, is accomplished, and then the heap is left undisturbed for some time, until the assays that are taken every day show that the operations should be hastened by the addition of fresh *magistral*, or made slower by throwing in lime, ashes, or other alkaline substances, and in either case following the addition by a thorough mixing by *repasos*. When the assays show that the mercury has been entirely taken up, a

second addition of about three-eighths of the quantity originally employed is made, and the tramping and daily assaying continued. A third, and even a fourth, addition of mercury is often found necessary; and when at length the assays show that all the silver in the heap has gone over into the amalgam, this treatment is discontinued, and the mass given over to the *washing*.

"SEPARATING THE AMALGAM FROM EARTHLY IMPURITIES.

"The entire heap, or *torta*, is now transported from the court where it has been treated, to neighboring vats, into which it is thrown, together with as much fresh mercury as has already been given, and a large quantity of water. Here it is stirred continually by means of a vertical paddle-wheel moved by four mules, and the amalgam, falling by its specific gravity to the bottom, is dissolved and retained by the fresh mercury, while most of the worthless material, remaining mechanically suspended in the water, is carried off. At the bottom of the vat will now be found collected the silver dissolved in the mercury, and a certain amount of heavy metalliferous matter, in which is contained some silver. The argentiferous mercury is separated from this mineral mass, and the latter, after concentration by washing, is given back to the amalgamation.

"TREATMENT OF THE AMALGAM.

"The liquid amalgam, after being removed from the vats, is put into strong canvas bags, through which the mercury percolates, leaving behind a pasty, argentiferous compound, consisting of about one-sixth of silver and five-sixths of mercury. This is moulded and compressed by proper apparatus into triangular forms, and is now ready to be given over to distillation.

"The triangular bricks of amalgam are piled in a column upon an iron grate above a reservoir of water, which is intended for the condensation of the fumes of the metal. The pile of amalgam is then covered with an iron bell, the edges of which are luted down, and the metal to be treated thus hermetically enclosed. Around the iron bell a wall of loose stones is constructed, and in the circular enclosure formed by this means a strong charcoal fire is made, and continued during eight, ten, and even twenty-four hours, according to the amount of amalgam treated and the size of the apparatus employed. The apparatus is then allowed to cool, and the mercury is found separated and condensed in the interior reservoir, while the silver, in a spongy form, and almost a pure condition, is removed and fused upon a hearth of bone-ash, moulded into ingots, and then sent to market.

"The duration of this process of amalgamation depends upon a number of circumstances; as, the nature of the minerals employed, the frequency of the *repasos*, and the purity of the re-agents. The temperature of the atmosphere in which it is carried on has also a great influence; the operation is conducted differently in the winter and in the summer, in the establishments situated in elevated regions and those near the level of the sea.

"When the circumstances are most favorable, the time necessary is about twenty-five days; but often it requires from forty-five to sixty days. Since accurate assays are seldom made, it is difficult to arrive at the loss of silver in this operation; but it is generally conceded that only from three-fourths to four-fifths of the entire amount in the ore is obtained. The loss of mercury is also variable, and depends greatly upon the care and knowledge of the directors of the work. In the most favorable cases it amounts to one-fourth of the weight of silver obtained, while under some circumstances it reaches one and four-fifths.

"The class of minerals which have been described as *negros* are either amalgamated directly, or subjected to a previous roasting. In the latter case, the amalgamation has been conducted nearly as has been described.

"The direct treatment of this sort of ore is, however, attended with much more loss of silver than takes place in the case above described, the loss being from thirty-five to forty per cent. of the silver present; or, in other words, it reaches from four to five times the loss incurred in the amalgamation in casks.

"In this plan of amalgamation practised in America, the silver of the ores is converted into the chloride, as we have seen was the case in the European

method; but it is here done by the wet way, instead of by the aid of artificial heat.

"The chloride of sodium, which is disseminated through the heap in a finely divided state, acts upon the sulphates of iron and copper of the *magistral*, and the sesqui-chloride of iron and the chloride of copper are produced. These, in their turn, act upon the silver, which is present in a native condition as sulphate or as sulphide, and the chloride of silver is formed. The quicksilver now decomposes this compound of silver, producing a sub-chloride of mercury, or calomel, while on the other side metallic silver is set free, and is dissolved by the mercury, producing amalgam. The loss of quicksilver is here necessarily greater than in the case of the European amalgamation, where it will be remembered the chlorine is made to combine with iron instead of the much dearer quicksilver.

"The following interesting extract from the books of the Real del Monte Company, one of the most important in Mexico, exhibits the relative expense of three systems of working the ores of silver, by barrel amalgamation, by amalgamation in heaps, and by smelting. The average yield of the ore in 1849 was 78 dollars (dollar = 3*s.* 10*d.*) per 3000 lbs.

"TABLE SHOWING PRODUCE OF SILVER AND COST OF EXTRACTION AT THE ESTABLISHMENT OF THE REAL DEL MONTE COMPANY.

Sources of expense for 3000 pounds of ore.	By barrel amalgam at Velasco.	By amalgamation in heaps at Regla.	By smelting at Regla.
Stamping; for labor	$00.59	$00.26	$00.30
Wear of stamp heads	.25	.28	.28
Grinding; mostly for labor	.70	.83	......
Drying and lifting; mostly for labor	1.20	......	......
Calcination; mostly for labor	1.76	......	......
Amalgamation in barrels and heaps; mostly for labor	1.04	3.98	......
Smelting in furnaces; mostly for labor	......	......	17.80
Wear of barrels	.30	......	......
Distilling amalgam and casting silver	.10	.05	.04
Repair of machinery, furnaces, etc	.60	.48	3.90
Sundry costs	.30	.40	3.40
Fuel, wood	3.31	......	1.00
Fuel, charcoal	.30	.20	34.90
Salt	5.37	3.64	......
Sulphate of copper	......	2.13	......
Litharge	......	......	21.50
Tallow and oil for machinery	.37	.10	......
Quicksilver	2.39	4.32	......
Steam power; mostly for fuel	4.23	......	......
Animal power; mostly for forage	......	......	......
Salaries, expenses of management	1.14	1.09	6.80
Total cost of reducing 3000 lbs. of ore	23.95	17.76	89.92
Mean produce of silver per 3000 lbs. of ore	94.80	65.92	514.40
Number of cargas (of 300 lbs. each) of ore reduced in 1854	53.895	37.982	2.386
Ounces of quicksilver lost for each $8.00 of silver produced	4.97	12.74	......

"Salt, it will be observed, is a large source of expense, since it has to sustain a land carriage of 300 miles; so that its cost at the mine is £16 10*s.* 6*d.* per ton. During the five years ending December 31, 1857, the mines of this Company produced silver to the value of £2,364,760."

PAUL'S DRY PROCESS—HOT AMALGAMATION IN BARRELS.

Mr. A. B. Paul, of San Francisco, taking advantage of the well known peculiar affinity of hot mercury for gold and silver, has, after many experiments, brought into practical operation the above interesting process, which he intends for the beneficiation of very refractory ores, in remote dry situations; it has been described in his pamphlet as follows.

"The ore is first dried, then reduced dry by such machinery as best suits the views of parties and accomplishes the object. The crushed ore is then conveyed to an iron pulverizing, preparing, and self-discharging barrel, where it is pulverized to a given fineness, and prepared for amalgamation, *under heat*, by the use of fire. By heat, friction, and chemicals, it is put in what I term an infinitesimal, electrical, live and pure condition. Thus, there is a combustion of all gases, destruction of rebellious films, and expulsion of atmospheric dampness, causing repulsion, instead of which is created the greatest activity, attraction, and cohesion between the precious metals *only*, and the mercury.

"The ore thus prepared being so fine and light, and the metal to be operated upon infinitesimal, the question now comes how to produce effectual contact for amalgamation. To meet this point, the ore is conveyed in its dry, heated, prepared, and electrical condition, to an iron, wood, or earthen cylinder, to which is added from ten to twenty-five per cent. in weight of mercury. The heated condition of the ore raises the temperature of the mercury, which lessens its density, increases its volume, and the result is, the ore and mercury play together like water, and create the most thorough and complete intermingling. So perfect is the blending, that on examination with the naked eye, hardly a particle of mercury is disclosed, notwithstanding the percentage to ore is so large. The mercury, in this finely divided state, having been in continuous motion, rolling over and over on the surface, and through the entire mass during the time given for amalgamation, it is reasonable to suppose has effectually done its work, and that the precious metals, no matter how fine, cannot escape a contact in this searching.

"The harmony created between precious metals and mercury is finely illustrated by the fact that the baser metals are placed in antagonism, and consequently leave the mercury free from the fouling or sickening properties of the ore, no matter what it contains. It will be observed, too, that every infinitesimal particle has had its weight increased by contact with mercury, besides being placed in a state to receive, more actively, the precipitating element.

"The operation, it will be admitted, is so far perfectly done; and the next question is, the separating of this mingled mass. To accomplish this, the ore from the amalgamating barrel is discharged into a large wooden settler, of especial construction, and where water for the first time is introduced. The greater portion of mercury, carrying the precious metals, is soon precipitated and collected for drawing off into a receiver. The lighter portions of mercury and metal in due time are drawn off into an electric settler, where they are precipitated by electricity upon the principle of electro-plating, excepting there is no adherence of metal or mercury, both of which are drawn off together. The residue is then allowed to flow off as wastage, or if desired, for concentration of base metals. A one thousand pound charge is worked every two hours, and yet every one thousand pound charge has over six hours of varied treatment.

"It will be observed that though considerable mercury is used, it does not involve having so large an amount on hand as at first thought would seem, in consequence of its being in continuous use.

"There are other essential points of equally practical character, but which are only given to those who engage in working the process. I present these views as to process, and its working, in as plain and comprehensive a shape as possible, that all may have some conception of it, and appeal to the common sense of practical miners for judgment in its favor. The process is a complete

revolution in our system of working, and is the result of a lack of respect for those in vogue, which with us have been so expensive, or defective and wasteful, that any new system having claims for practicability stands a show for superiority.

"The system has not originated from laboratory experiments, but deduced from the practical and successful working out, *in the mountains*, of complicated difficulties"

THE SEPARATION AND EXTRACTION OF GOLD AND SILVER FROM THE BASE MINERALS AND MATRICES, BY VERY HOT WATER OR HYDRATED SOLUTIONS OF THE CHEAPER SALTS, AS PRODUCED BY FIRE, AND SUSTAINED FOR A SUFFICIENT TIME IN LARGE AND SUITABLY STRONG FIXED OR REVOLVING CLOSE VESSELS, UNDER THE HEAVY PRESSURE WHICH IS DERIVED FROM THE FORMATION OF STEAM.

Chapter II, Section I, of this book treated of the various transformations during high temperature, under the pressure existing at the initial period of secondary formations, from primitive rock elements and general debris; the reader may now refer back to page 26, and carefully peruse that chapter, so as to understand the general nature of water, more particularly as regards the increased heat which may be produced by pressure, and its consequent effects on minerals and matrices. This was then the effect of the natural state of affairs; and if by heat and pressure we create a similar action in a close vessel, which contains a strong solution of say chloride of sodium, you may well suppose that as silver is soluble therein, under ordinary circumstances, by a slight increase of heat, that a much greater temperature will cause the effect of speedy and cheap solution, which will lead to the precipitation of the silver from such solution by any one of the ordinary internal, and simultaneous, or external and subsequent means.

A large vessel may be readily made, so as to treat many tons at once, in these days of giant powers for execution of iron work by steam hammers, which will stand all the pressure that is necessary for actually decomposing the ore in such hot solutions; and I think that such an experiment would lead to very important means for beneficiation of peculiar ores, whilst the ordinary forms will be much more readily reduced.

This digestor being cylindrical, might be slowly revolved,

to circulate the pulp, and offer a changing, moist surface to the action of the fire; whilst a safety valve should be attached to a suitable pipe, which communicates with the barrel by way of the end trunnion.

Or it might be fixed on solid trunnions, to oscillate slowly from side to side, with the valve on top.

After a sufficient amount of experience, the valve may be entirely discarded, as a certain known amount of fire will act sufficiently near, the one time with another, to produce the desired pressure and effect.

The *charged vessel* may be deserted and allowed to work its own digestion, so that no fatal effects need be caused by explosion, even if it should ever occur during the preliminary trials as to what degree of heat and pressure will be necessary.

This is, of course, a suggested process; but its plausibility warrants a trial, more particularly with the strong chloride solutions, which are not only slow solvents under ordinary circumstances, but have, in this connection, the very desirable property of greatly increasing the temperatures of the liquor under the various pressures, so that very high pressure will be unnecessary.

CHAPTER III.

CHLORINIZING.

ROASTING, FOR THE VOLATILIZATION OF SULPHUR, OR ARSENIC, AND THE OXIDATION OF THE ENCLOSING BASE METAL, FOR THE SUBSEQUENT CHLORINIZATION OF THE FREED GOLD FROM THE MOISTENED DEBRIS OF ORE, AND PRECIPITATION OF METALLIC GOLD FROM THE DILUTED SOLUTION.—FURNACE CHLORINIZATION AND REDUCTION OF SILVER, AND OF GOLD AND SILVER, WHEN ASSOCIATED WITH BASE MINERALS.

PLATTNER'S ORIGINAL METHOD FOR THE BENEFICIATION OF REFRACTORY AURIFEROUS ORES, BY ROASTING, HUMID CHLORIDATION, AND PRECIPITATION.—Since the first introduction of this method by Plattner, but little improvement has been made in its manipulation, whilst the process remains substantially the same.

It may be easily accomplished by the following method.

1. Roast the finely pulverized, naked ore, in the manner described at page 504, in any appropriate furnace, as the Cornish rotating-table calciner (page 501), or the common reverberatory furnace (page 498), or the hill-side roaster (page 504), at a red heat, for from six to twenty-four hours, dependent on stirring, the addition of charcoal, constitution, etc., until no blue flame is produced from the combustion of sulphur, nor sparks appear when the pulverulent ore is tossed from the hearth.*

* When the raw ores contain the calcareous spars, heavy spars, or talc, five per cent. of salt may be used to advantage in roasting, which also cleans the surface of gold, and serves to volatilize the small quantity of copper that is frequently present. Lead and antimony, however, prohibit the use of salt, when roasting for the humid chloridation of gold.

If you want the chloridation effectual, the roasting must be completed until no such signs of sulphur remain.

2. The completely roasted ore may now be withdrawn from the furnace, spread on a hard flat surface, cooled down with water, then well stirred or shovelled into a paste, of such state of moisture that water can neither be seen on its surface, nor squeezed out on the hand; so that a little time should be given for equal absorption.

It is important that this auriferous desulphurized and oxidized debris should not be made too wet with water; for, if so, more chlorine will be required for obtaining the same strength of chlorine water; and the chlorine gas cannot be so effectually passed up through every portion of the mass, when it is placed in the tub or cistern, for chloridation, when the pulp is sufficiently wet for settlement to closer contact. It is, moreover, unnecessary; for the amount of gold that has to be dissolved is so comparatively small that this quantity of chlorine water will be found all-sufficient for its solution.

3. The most convenient and effective vessel for dissolving the gold is a round tub, of about seven feet in diameter and thirty inches deep, which is supplied with a suitable bottom for the transmission of the gas throughout, that it may pass in an equal manner through the ore; this may be done by a perforated disk of wood or wicker-work over a hollow bottom, or by placing upon clean coarse stones some permeable material, as canvas or coarse woolen.

4. Some of the ore may now be charged in a loose manner, by sifting, to about one-fourth the capacity of the vessel, so as to be ready for the action of the chlorinized water, that dissolves the free gold released by effectual roasting from the base mineral's embrace. As soon as the heavy gas is observed above this charge, more of the roasted ore may be added, until the tub is about three-fourths full.*

5. This water is chlorinized by chlorine gas, as generated in an adjoining *close leaden vessel*, so arranged on a sand-bath over a fire, that the necessary auxiliary heat may be

* Such a tub may be made to treat the resultant roasted residue of three tons of ore (about two tons), which require of the oxide of manganese thirty pounds, of common salt forty-two pounds, fifty pounds of water, and sufficient sulphuric acid for decomposition.

safely applied during its production, by the action of sulphuric acid on a mixture of four parts of common salt, three of peroxide of manganese, and five of water.

The tub which contains the ore should be lastly covered and luted with moist dough, in a gas-tight manner, and be supplied with metal or rubber tubes, to convey the surplus and poisonous gas out from the room.

Two pipes should also be inserted in the false bottom, the one for the supply of gas from the generator, and the other for the withdrawal of the diluted solution of chloride of gold, at the termination of the dissolving stage.

The gas generator should be provided with a funnel and *bent tube*, to serve for supplying the acid at any time, in requisite quantity, and to prevent (on the stink-trap principle) the rising of the gas through this necessary tube.

A glass or porcelain vessel, or another wood tub for the large scale, will be also required for receiving the chloride of gold solution, when drawn off for precipitation.

The ore being thus roasted, moistened, loosely sifted, and closely covered in the wooden tub, the rubber or lead tube may be united to communicate therewith from the supplying pipe of the gas generator; then sulphuric acid should be slowly added, and gentle heat, until chlorine gas is seen to escape from the last tube without the house, when but just a sustaining quantity should be supplied.*

The gas being much heavier than air, lies upon the moistened ore, after saturating the water, and still continues to support the strength of the liquor during its action on the gold. The surplus gas may be—in fact, should be—drawn off, by a pump, into a suitable reservoir, for beneficiation of the next batch of ore.

Some fourteen or fifteen hours are generally required for complete solution of such *fine gold as should have passed through the wire gauze of* 1600 *per inch*, when sufficient hot water must be added for running off the solution into the

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* Chlorine gas (in this instance) may be most easily detected by dipping a wooden or glass rod in ammonia, and applying it to the discharge pipe, when the smallest trace will expose clouds of white vapor, similar to that from hydro-chloric acid.

The rod may be dipped in nitrate of silver, when a white curdy chloride will be formed thereon, in similar position.

precipitating vessel; then a little more hot water, for removing the last traces of gold chloride, that would otherwise adhere to the debris, and be lost. This ore may be removed for repetition of the process.

6. Sulphate of iron, in liquid state, is now added to this liquor (which should be acidulated by a few drops of hydrochloric acid), until no more gold can be precipitated. It need not be run off until just before the next precipitation, nor the precipitated gold cleaned up for being run into ingots, but as convenient quantity dictates.

The precipitated gold, after being well washed, may be dried, and smelted to marketable condition, as described at pages 285, 286, 287; and as little or no base metals are present, borax will be an efficient flux.

It has been fully proven that from ninety to ninety-four per cent. of the fire assay can be realized by this means, when properly conducted; whilst the gold is then of from $\frac{991}{1000}$ to $\frac{996}{1000}$, and finer than by any other practical method.

Mr. Guido Küstel, in his especial and comprehensive work on "Concentration and Chlorination," gives the following items of costs for chloridation of auriferous sulphurets, by this process, in California, as estimated from the daily run, from a long double furnace, of three tons of sulphurets, in the year 1868.

"Superintendence	$ 6.00
Four roasters, at $3.50	14.00
Three cords of wood, at $4	12.00
Thirty pounds manganese, at 6¼ cents	1.87½
Forty pounds salt, at ¾ cent	.30
Seventy-five pounds sulphuric acid, at 2½ cents	1.87½
One man at the mats, two days, at $3.50	7.00
Sulphate of iron	.60
Total cost of three tons	$43.65

Or $14.55 per ton of sulphurets."

FURNACE CHLORIDATION AND BENEFICIATION OF SILVER, WHEN MIXED WITH GOLD.

This operation has been fully described under the appropriate heading of "*Roasting and chlorinizing of the mixed ores*

of silver and base metals, for more effective amalgamation," and may therefore be referred to at page 509, and considered here but so far as concerns the mixture of silver with gold, to prevent the entire loss of the former metal, during the humid chloridation of the latter.

It has been stated that the addition of salt is frequently advantageous for facilitating the roasting of auriferous sulphurets, which may therefore be now extended to our purpose for the beneficial extraction of both silver and gold, when the former is also present in notably profitable quantities, by using sufficient salt for bringing the silver into the non-volatile and insoluble chloride form, for subsequent beneficiation, which may be accomplished by one of the following methods.

1. Chlorinize and precipitate the gold by Plattner's process; then treat the residue by amalgamation in barrels, arrastras, Chilian mills, or pans, for its chloridized silver and any free gold which may still remain.

2. Treat for both gold and silver, by amalgamation in close barrels or improved arrastras, when the difference of cost will be about equal to the deficiency of returns.

3. Chlorinize for gold, in *revolving wood barrels*, instead of *in tubs;* draw off the chloride of gold liquor, *for precipitation;* then finish for extraction of silver by *amalgamation.*

I suggest this for trial, as it appears a better and quicker method for even the chloridation of gold, and which also amalgamates the silver. The barrel is the most efficient amalgamator, and there is no reason why it will not also chlorinize better and much faster than tubs.

Two revolving barrels may be used, the one large for the moistened roasted ore, and the other of suitable size for holding the materials for formation of the gas; they may be made to communicate through a hollow axle, and be supplied with ore and discharged through individual bung-holes; or be so arranged that one gas generator shall supply the whole of the barrels, by tubes through each axle, or bung-hole.

4. Chlorinize for silver in furnace, and for gold by Plattner's process; and then extract the silver and copper by one of the chemical processes described in Chapter V of this Section.

CHAPTER IV.

SMELTING.

SMELTING BY NATURAL DRAUGHT, IN REVERBERATORY FURNACE; BY BLAST, IN CUPOLA FURNACE; AND BY VARIOUS EXTEMPORE MEANS.

To afford full information on this subject would require a very large book, and even for general instruction, with historical and statistical data, more space than can be afforded in this work; we will therefore conform more to the necessities of the miner of remote sections than to metallurgical perfection.

Before entering into the subjects of actual smelting, it will be well to refer back to the commencement of Chapter I of this Section, on "Roasting," for refreshment of memory in this, its initial stage; as it should be fully considered, or unnecessary losses will result: for *all ores* cannot, and will not, for some considerable time hence, be advantageously smelted into metal.

In this connection, it should be also considered whether there is a sufficient local market for large quantities of such metal; for this fact alone, from double-carriage reasons, frequently decides whether ores should be smelted on the spot.

This will more particularly apply to argentiferous lead, iron, copper, zinc, and antimony, with consecutively diminishing importance.

THE SMELTING OF LEAD ORES IN REVERBERATORY FURNACE, BY THE ENGLISH METHOD.

It will be generally more advantageous to smelt argentiferous lead than the other above named ores; and we will first select and describe the most simple means for the reduc-

tion of its more difficult, but frequently argentiferous and profitable ore, the sulphuret of lead, or galena.

This is considered the best and most exacting method for the reduction of galena, and the other ores of lead.

You will see at page 498 (Cut 45) a vertical section through a suitable furnace for this purpose, which was there described in all ways excepting its dimensions, and the manner of slope towards the tap hole and iron kettle, which may be supposed to lie at about the middle of the hearth, at the further side, and which is hidden by the wall of the furnace itself.

The body of the hearth is so shaped that the smelted lead may naturally descend to, and accumulate into, a suitably large pool, for occasional withdrawal through the clay-stopped tapping hole, by the aid of a properly pointed bar, into the kettle and moulds. The great expense for a chimney can be avoided by an ascending flue in the mountain side.

The length of the hearth may be...............	10 feet.
The breadth of the hearth........................	7 feet.
The height of the roof above the hearth at bridge end	1 foot 4 inches.
The height of the roof above the hearth at chimney end....................................	1 foot.
The breadth of the fire-place	6 feet.
The length of the fire-place......................	2 feet.

The charge of closely concentrated ore for such a furnace may range from 2000 to 3000 pounds, as governed by knowledge and practical skill in manipulation. More than this amount of closely concentrated galena is frequently smelted in the Cornish lead works.

In the smelting of the sulphuret of lead, it will be interesting to notice the following re-actions, which have been most subservient for the smelter's purposes.

"*Roasting in contact with a current of air* transforms galena into a mixture of the *oxide* and the *sulphate* of lead, while fumes of sulphurous acid are given off.

"*When galena is fused with metallic iron, c pper, antimony, or zinc, it is decomposed with the formation of metallic lead.*

"When iron is used in this connection, the lead may be

almost entirely separated from the sulphur, since the tendency of iron to alloy with lead is very slight, in a state of almost complete purity. *If the galena contain at the same time sulphide of silver, it will experience the same decomposition, and the lead and silver will be found in the form of an alloy, while the iron will be converted into the sulphide.* This re-action is frequently taken advantage of for obtaining rich lead upon a large scale. It forms the basis of the method employed on the Hartz, in various parts of central Germany, in Hungary, and in Sweden.

"*When a mixture of galena and the oxide of lead are fused together, there is a mutual decomposition; and if the proper proportions are employed, all the sulphur will go off as sulphurous acid gas, and only metallic lead will remain.*

"Thus, if 53.6 parts of galena (representing one atom) and 100 parts of the oxide of lead or litharge (representing two atoms) are, while in contact, brought to a white heat, the sulphur and oxygen combine, forming sulphurous acid, and 139.2 parts of pure lead are obtained.

"If *galena*, in this experiment, predominate, a portion of the sulphur will be combined, and a *sub-sulphide of lead* will remain; if, on the contrary, the *oxide of lead* is in excess, *metallic lead* and *litharge* will be the result; but when a mixture of the two substances is only raised to a heat just sufficient to fuse them, a *grey oxy-sulphide* will be obtained.

"*Galena and the sulphate of lead decompose each other mutually, when brought to a red heat.* Thus, 78 parts of galena (representing one atom) will give sulphurous acid gas, which goes off, and 127 parts of pure lead.

"If *galena* and an *excess* of the *sulphate of lead* be fused together, the *oxide of lead* will be obtained instead of the metal.

"The *sulphate* and the *sub-sulphide* also re-act on each other, producing, according to the proportions employed, *metallic lead* and the *oxide of that metal. If, in any of these cases, silver is present, either as an oxide or a sulphide, and metallic lead is produced, the silver will be reduced, and will be found alloyed with the lead.*

"These re-actions are of immense importance to the lead

and silver smelter, since upon them are founded the larger number and most extensively used methods of obtaining lead and 'rich lead' from the ores of the two metals."—*Dr. Lamborn.*

The portions concerning metallic scrap iron, for the formation of double sulphides, may be disregarded in new countries; and as its scarcity prohibits its application, it will be useless to describe this mode of smelting.

The furnace having been thoroughly dried and brought to a low red heat, the charge of say 2000 pound of galena (*which should be broken to the size of peas, and so closely concentrated that it shall contain not more than one or two per cent. of quartz*) may be now dropped from the hopper into the furnace by withdrawing its sliding gateway, and distributed over the hearth with the rake, when the following operation may be performed.

1. *Roasting the ore under rapidly increasing heat and free access of air, for the partial decomposition of the ore into oxide and sulphate of lead, whilst some sulphide still remains undecomposed.*

This generally occupies some three or four hours, is performed in the manner described under "Roasting, at page 499; but care should be taken, in this instance, that complete desulphurization *shall not* be accomplished:

2. *Reducing some of the ore to metal by increased heat and exclusion of air.*

The doors must be now quite closed, and the fire urged until the greatest possible heat is attained, when the reduced lead is tapped off and ladled into moulds. During this period, metallic lead, the sub-sulphide of lead, and sulphurous acid are formed.

3. *Repetition of the first process, for further decomposition and re-action as before, by the further admission of air and the partial cooling of the mass of slag.*

During this cooling, the sub-sulphide has the peculiarity of setting free some of its lead, by increased affinity for sulphur, which directly increases the quantity of lead, whilst more ore is also prepared by repetition of the roasting.

4. *The second smelting, or reduction, may be now accomplished as under the second heading, and the resultant lead cast into moulds as before.*

These desulphurizations and reductions are repeated until no more lead can be obtained from the tapping-hole.

In the last one or two *smelting* stages, a little limestone (if there is not any in the ore) may be added (in a powdered state), to keep the mass more spongy and less adhesive; and some charcoal, so as to reduce more lead than would otherwise be accomplished.

The sulphuret of antimony should not be present in any quantity, as it will interfere with the early roastings; and quartz, by forming a too liquid slag with the oxide of lead, will also clog and prevent the necessary initial re-actions, that must transpire for the effectual reduction of lead by this mode for smelting.

It will be generally advisable to collect the various fumes in suitable chambers, *en route* to the chimney top, which rooms, being much larger than the flue, serve to deposit, during the slower travel, the oxides of lead, or antimony, as well as some of the sulphur and sulphurous compounds. Sometimes, showers of water are provided to fall at one or more points of the flue, to more effectually precipitate the impalpable oxide powders; whilst, at other times, various mechanical appliances have been used, so as to force the whole of the fumes through water. I have now before me an English device for this purpose, which will be interesting in this connection, just now.

"*Bennett's apparatus for condensing lead fumes*" was described in the "Mining and Smelting Magazine," at the commencement of the year 1865, in editorial language as follows.

"In plate 1, figures 1 and 2, we give drawings of Mr. Frederick Bennett's condenser, as erected at the St. Cuthbert lead works. As already stated, this apparatus consists essentially of a fan wheel on the principle of the Archimidean screw, working immersed in a certain depth of water, in a cylindrical chamber, through which all the lead fume and smoke pass from the furnaces to the chimney. The wheel being put in rapid rotary motion, the lead fume and smoke are drawn in, and the water at the same time projected by centrifugal force as spray towards the periphery of the wheel, by which the fume is forced into intimate contact with the water, and the lead thus condensed. The water and fume, thus mixed together, being continued to be propelled forward by the screw, find an outlet at the end of the chamber into a circulating tank on either side; from which circulating tank this liquid is again drawn into the chamber by the suction of the wheel, to take up fresh fume: an operation which is continuously repeated until the liquid becomes sufficiently saturated to be withdrawn into the depositing or settling tanks, when a fresh quantity of water is supplied." * * * * * * * * * * * * *

All mechanical auxiliaries, however, appear to be quite

unnecessary, as a shower of water will cause all such fumes to be condensed or precipitated in an equally efficient manner.

Those who fear that the draught would be thereby retarded may build the flue so as to descend in a vertical manner for a few feet, just where the shower of water falls, and the very reverse effect will be the result.

The more general, and by far the most difficult ore, for being smelted, is the sulphuret, or galena; the oxide and carbonate are less frequent, but much more easily smelted, requiring but sufficient heat in a close furnace, in presence of the carbon of the fuels.

THE SMELTING OF COPPER IN THE REVERBERATORY FURNACE, BY THE ENGLISH METHOD.

The following data, taken from the Philosophical Magazine and Journal of Science, Vol. IV, as written by J. Napier, F. C. S., will be interesting and valuable for you.

"1. The copper ores must not be under 9, nor over 13 per cent.; if under the former, it is unprofitably poor; if over the latter, the slags have a tendency to contain copper, creating a loss.

"2. The mixture, after undergoing an ordinary calcination, should fuse easily without the necessity of adding flux, giving a clean and easily fused slag.

"3. The matt, or coarse metal obtained from the first fusion, shall contain, as nearly as possible, 30 per cent. of copper.

"4. The impurities, which will make the quality of the copper lower than that determined upon, should be rejected.

"In forming this working mixture, the rich oxides and carbonates are not used, but are retained to be brought in after the reduction is partly completed.

"The average composition of all the ores smelted at one of the Swansea works, during a considerable period, was as follows:

Silica	38.5
Alumina	2.4
Lime.	0.3
Magnesia	0.4
Copper	13.5
Iron	19.7
Other metals	0.9
Sulphur	23.1
Carbonic acid — oxygen and water	1.2
	100.0

"But, in considering the reactions which take place as we follow the various processes, we may regard chiefly four of these substances, and consider the ore made up of—

Copper	13 per cent.
Iron	29 per cent.
Sulphur	24 per cent.
Silica	34 per cent.
	100"

The following are the most salient features of the several distinct processes for smelting and refining of copper by this method.

1. *Roasting the mixed ores, for the partial volatilization of sulphur.*

2. *Smelting coarse metal from the roasted ores.*

3. *Calcination of coarse metal.*

4. *Fusion of the roasted metal.*

5. *Roasting the partially refined metal.*

6. *Completion of the refinement by poling.*

Those who may require to thoroughly smelt and refine copper may take the marketable sulphide matte, as roasted and smelted under the first and second headings, in the manner described at pages 498, 499, and 500, and treat it in the same, or in a similar furnace, as will now be successively described under the third, fourth, fifth, and sixth headings.

The fuel used in England is coal.

PROCESS III. CALCINATION OF THE FIRST COARSE METAL, OR SULPHIDE MATTE FROM PROCESS II.

The object of this second roasting is to volatilize more sulphur, antimony, and arsenic, and to oxidize the copper and iron, so that the former may be smelted to greater purity.

The coarse and friable metal is first bruised to a granular state; then it is charged through the hopper, spread over the hearth, and roasted in a similar manner to the ore, taking care that the heat shall be gradually increased, during occasional stirring for some twelve hours, to but a red heat, which should be continued until twenty-four hours have expired from the commencement of the roasting; when the charge may be raked from the furnace and cooled down by water, which releases more sulphur by the formation of sulphide of hydrogen gas.

It is now ready for the next smelting.

PROCESS IV. FUSION OF THIS ROASTED COARSE METAL.

To manage the charge in the most efficient manner as to the profitable introduction of rich oxides, carbonates, cuprif-

erous slag, broken hearths, or copper scales, and to know by the appearance of the fused contents when the proper appearances are presented, is probably the most difficult manipulation of copper smelting, for herein lies the facility for realizing greater profit, or wasting unnecessary fuel and labor.

A certain amount of such more easily reduced copper may be thus produced, to increase the quantity of what would be otherwise obtained at the same smelting cost; so that any quantity of such that might have been, but was not added, would have occasioned unneccessary loss.

A common charge may amount in total to 4000 pounds of a mixture of about equal weights of the roasted metal from Process III, and one or more of such more easily reducible compounds, with about ten per cent. of the resultant slags from the previous smeltings under Processes V and VI.

This being charged through the hopper, and spread evenly over the furnace, all of the doors are closely luted, and the fire is made to play thereon for some three hours, until the mass has arrived at a partial state of fusion with a molten sub-stratum of metal and thick crust of semi-fused matter. The fire is now urged to its full strength until this also becomes fluid, which may be accelerated by occasional stirring and transferrence of the thick lumps to the hotter part of the hearth.

In about six or seven hours this smelting is completed, when the slag may be skimmed off, and the underlying metal tapped to fall into water for granulation, or be run into suitably shaped sand moulds, to form pigs.

By this means, the iron has been oxidized and removed from the charge of roasted copper, by union with the silica of the ore, the slag, and the hearth; whilst more copper is reduced by simultaneous changes at high temperature, forming "blue metal," which should be composed of copper 73, iron 6.5, and sulphur 20.5 (sub-sulphides of copper and iron).

The slag is principally composed of proto-silicate of iron, with from one to two per cent. of copper, which should break easily into glassy sharp-edged fragments.

This slag is mixed with the charge for, and beneficiated under, Process II.

PROCESS V. ROASTING THE BLUE METAL.

About three tons of "blue metal" pigs may be now introduced, on suitably flattened long-handled bars, so as to occupy separate places on the hottest part of the hearth.

The doors must be closely luted, and the furnace heated to the melting heat of copper, so that the metal may be slowly melted to fall from the pigs in innumerable drops, for its more speedy and effectual desulphurization.

This continuing and increasing heat will soon render the whole contents perfectly molten, and more sulphurous gas will continue to be evolved from the boiling fluid; the doors of the furnace must be opened to supply oxygen, when the gradually cooling mass will form a surface encrustation, as the underlying pool continues to boil and pass off sulphurous acid gas. When the temperature is so low that this action becomes retarded, the doors are closed, that thorough melting may be accomplished, for a repetition of cooling, as before, and again and again, if necessary, until but little gas escapes, when the doors should be firmly closed, and the fire be increased during a period of five or six hours, to its utmost heat; during the former part, the remaining gas will escape, and when the temperature becomes sufficiently high, the silica thus fused from the furnace will unite with the metallic bases present, to form a slag, which floats on the surface of the still more or less impure alloy, that varies from ninety to ninety-eight per cent. of copper, associated with sulphur, iron, antimony, tin, and silica.

These re-actions are produced in about twenty-four hours.

The extensive smelters, knowing every demand for various alloys thus produced, frequently stop here, and sell accordingly; and sometimes, when comparatively pure copper is only required, they beneficiate a portion of this smelting by taking advantage of the fact that the other metals, being more fusible, by giving their sulphur to the copper, are first reduced to metal, and can be separated by being tapped off, when about one-quarter of the whole is melted, before the more infusible fine copper has been reduced to molten condition.

PROCESS VI. REFINING AND TOUGHENING OF THIS ALLOY.

There are, properly speaking, two important principles applied in this manner of refinement, the first for the further riddance of sulphur, iron, and zinc, and the last for the complete expulsion of arsenic, antimony, and tin; so that when the latter are not present, the poling may be sometimes unnecessary.

For this smelting, the same, or a similarly shaped furnace, may be used; but, as the metal is generally ladled into suitable moulds, an opening should be provided for the passage of the ladle into one of the fire-end corners, towards which the bed of the furnace should slope to form a pool.

As the present object is more simple than those of the past, about six tons of metal may be introduced as in the last instance, and after the doors are closed, the fire must be urged until the copper becomes molten; the slag may be now removed from the surface of the metal, to expose it for more effectual oxidation and discharge of the sulphur, iron, and zinc, which volatilize, or combine with silica to form still more slag.

The air is allowed to flow over the surface for some time after the motion created by the escape of gas has ceased, so as to ensure the formation of a sufficient amount of the sub-oxide of copper; and when the furnace-man is satisfied, from the appearance of an especially drawn sample, that the sub-oxide of copper has been formed in appreciable quantity, it will be safe to say that the first stage for purification has been accomplished.

The last purification may be now proceeded with, for the removal of those metals (arsenic, antimony, and tin) which had too strong affinity for copper in molten state, as compared with silica or oxygen, for separation by the above means.

The partially sub-oxidized molten copper must be now completely covered with pulverized anthracite, or charcoal, to prevent further oxidation of the copper; whilst that already oxidized is again reduced to metal by the insertion of a green pole, or branch of oak, birch, or other suitable, substantial, slow-burning wood. This consequently bears

the name of "poling;" for whilst it is being subjected to high temperature, the requisite changes take place.

Many reasons have been given for this effect; but none that I have seen are sufficiently clear or satisfactory. (*So far as the reduction of the sub-oxide to copper is concerned, it is probable that when the wood is brought to high temperature, under the surface, and apart from all other sources for oxygen than that of the sub-oxide of copper, its affinity is much more intense for it, than the oxygen for the copper, so that stifled combustion or oxidation of the elements of wood takes place; whilst the products of combustion, carbonic acid and water, in forcing their way to the surface, may also oxidize and carry the arsenic, tin, and antimony away, for subsequent oxidation by the hot furnace oxygen.*)

This operation generally occupies but about a half-hour, and as it may be overdone, careful examinations should be made on small quantities drawn from the furnace, as to hardness, color, ductility, and toughness; which can be best seen by flattening to thin disks under the hammer or sledge. Its color and hardness are easily recognized, and its ductility and tenacity may be as readily seen by the thinness of the disk, and freedom of its periphery from cracks.

If it is over-acted, the metal will appear too pale and hard, and the process must be repeated.

It is then ladled into large or small ingot, tile, or bar moulds, to suit the different markets, which will greatly depend on the purposes for which it is required.

It is also sometimes granulated, by falling into cold water, to thin "feather shot;" and by falling into hot water, to "bean shot," which are more suitable for the small operations of the manufacturer.

Copper ingots are sampled for average by drilling through, and may be assayed best by the humid means.

When copper works are placed on hill-sides, and have excavated flues and chimneys, the fumes should be retarded and arrested in large chambers, so as to beneficiate the volatilized sulphurous compounds, that would otherwise escape and be wasted.

Complicated and difficult as this English system appears, the French and German modes are even more so; whilst the number of processes are also in excess.

THE SMELTING OF TIN OXIDE IN REVERBERATORY FURNACE.

These ores are finely pulverized by the miner, for concentration and separation by water treatment of all deleterious gangue matter, and for removing by fire, as described at page 500 and following pages, of such as cannot be passed away in water.

It has been the practice for the miner to closely purify this ore, even by roasting when necessary, so that the smelter may reduce it to metal forthwith.

A furnace of the general form shown by Cut 45, page 498, may be used, except that the top should be made lower, or closer to the hearth; whilst the bottom and bridge are provided with underlying air chambers, to prevent too great a heat, and increase the duration of the fire-resisting materials of the furnace.

One ton of this finely pulverized, properly prepared ore is mixed with about sixteen per cent. of anthracite ("culm") and a little common lime or fluor spar, and spread over the hearth, when the openings are closed and the fire forced to full combustion for some seven or eight hours; the charge must now be well raked and stirred, so as to break and mix the undissolved clods with the molten mass; then the doors may be again closed until the whole contents are fluid. Some moistened ash should be thrown over the whole surface, to serve as a means for cleansing the metal from dross, by collecting it into a slag, which may be easily raked off before the metal is tapped into a suitable iron pot (as that for lead).

Shortly after the metal has been drawn, the slag that ascends to the surface should be skimmed off, and the metal ladled into various suitably shaped moulds.

This metal, even after every preliminary care, is more or less alloyed with the chance associates of arsenic, bismuth, copper, iron, lead, etc.; so that, for some markets, it is imperatively necessary that the alloyed metal should be refined, which is done somewhat after the manner described in "Copper Smelting."

This coarse tin may be refined by being placed in the furnace, under a very gradually increasing heat, by which the more fusible pure tin is first smelted, drawn off at the proper

time, and "poled" like copper, but with a bundle of wet limbs, which, by forming gases and steam, bring the metals to the surface, for oxidizing into dross; whilst the yet unfused alloy, that contains less tin, remains in the furnace. The fire is now increased until this is also melted, when, after the first drawn and purer tin has been ladled into moulds as "bar tin," or broken at the proper heat into "grain tin," the last smelted may be tapped and ladled off into moulds, as "block tin."

Here, as in the copper trade, the large European smelters command many advantages, from knowledge of the requirements of the many different manufacturers.

SMELTING OF THE SULPHURET OF ANTIMONY IN VERTICAL, CYLINDRICAL RETORTS AND CRUCIBLES, WITHIN REVERBERATORY FURNACE.

This mineral cannot be successfully smelted in the open fire, as the preceding ores of lead, copper, and tin, unless largely mixed with them as an alloy; for, although it cannot be entirely evolved from them very promptly, it is as difficult to reduce it to metal when alone.

It frequently happens that the alloys of lead, tin, and antimony are marketable as such, so they can be smelted by the methods already given; but when the solitary sulphuret of antimony is required to be reduced, there is probably no better method than that used in the Malbose Mines, France, which has been described as follows by Mr. G. H. Makins, in his "Manual of Metallurgy."

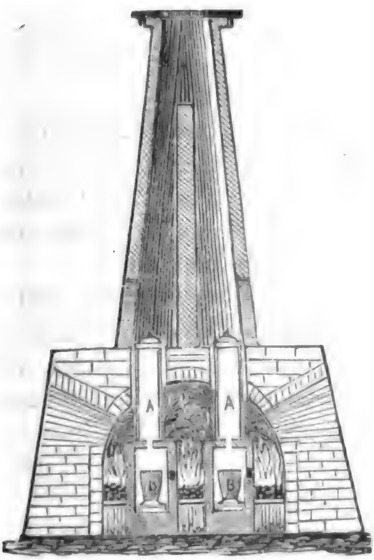
"At these mines, the operation is performed in a reverberatory furnace, but constructed with a dome-shaped arch—that is, arched each way; underneath this is placed a set of four fire-clay cylinders or retorts, A, which rise perpendicularly through rather larger openings in the arch; these openings being covered by fire-clay covers. The cylinders stand perpendicularly upon the strong cover of an oblong chamber formed below on each side, wherein a crucible, B, is placed immediately below each cylinder, for the purpose of receiving the liquid sulphide, which passes from the clay cylinder down into the crucible by a hole in the chamber cover. The grates run from back to front, and are placed on each side of

the crucible chambers, at about the level of the pots, the heat being allowed to pass into them by flues.

"In working, the crude ore is put into the clay cylinders, and wood fires are kindled upon the grates, the draught of which is kept up by a chimney which rises over each pair of cylinders. As the sulphide fuses out of the ore, it passes down, and is received in the crucible below; the latter, being of cast-iron, is lined with clay, in order to get the cake of sulphide out more easily when cold. The operation upon a charge of ore occupies about three hours.

"The product so obtained is commercial crude antimony, which is really a sulphide. From this the metal is obtained, by first powdering it, and then heating upon a reverberatory bed, a roasting or dull red heat being employed. By this, much of the sulphur is driven off, together with any arsenic which may have been present; some oxide of antimony is generally lost, also, during this roasting. The two former escape as sulphurous and arsenious acids. The residue, which consists of a mixture of teroxide and tersulphide of antimony, is now worked up with one-fifth its weight of charcoal, which has been previously saturated with a strong solution of carbonate of soda. This mixture, placed in crucibles, is heated in a wind furnace to bright redness; thus the metal is reduced, and sinks to the bottom of the pots, under a slag composed of sulphide of sodium with sulphide of antimony. This latter is separated from the pure metal and sold as 'crocus of antimony.' The yield of metal, owing to this and other loss during its extraction, always falls short of the equivalent contained in the ore. The metal itself is known as 'regulus of antimony.'

Cut 54.



"Chemically pure antimony is best obtained by Wohler's method, which is as follows. Four parts of metallic antimony are powdered with two of dried carbonate of soda and five of nitrate of soda. This mixture is heated to redness, when oxidation of the antimony and arsenic (if the latter be present) takes place at the expense of the oxygen of the nitrate of soda, and antimoniate and arseniate of soda are formed. When deflagration ceases, the pasty mass is kept over the heat for about half an hour, the operator now and then squeezing it with an iron spatula; after which, it is removed, and, when cold, powdered and thrown into boiling water; this dissolves away the arseniate, while the insoluble antimoniate is left; this is well washed with hot water. It is then removed, dried, and fused with half its weight of crude tartar. The product of this fusion is next broken up and thrown into water; a copious evolution of hydrogen is at once set up from the oxidation of the potassium, for the mass so treated is an alloy of antimony and potassium. The residue of this action is a powder composed of antimony, with any iron and lead which may have been contained in the original metal. To remove these, about one-third of the powder is treated with nitric acid, so as to oxidize it; this portion, when washed and dried, is mixed with the residue of the metallic powder, and the two fused together in a covered crucible, by which the pure antimony is separated and subsides under a slag composed of the foreign oxides."

SMELTING OF ZINC ORES BY THE ENGLISH METHOD; IN LARGE CRUCIBLES PLACED WITHIN DOME-SHAPED RETORTS, AS HEATED BY AN INTERNAL FIRE, AND COVERED BY ITS DRAUGHT-CREATING CHIMNEY.

Zinc ores closely resemble the antimonial in their actions during reduction by fire; so that equally unusual means must be resorted to before the metal can be obtained.

There is probably no method more simple, effective, and exacting, than that called the English, which is generally performed in the following manner, in a kind of muffled furnace, somewhat similar in form to that used by glass-blowers.

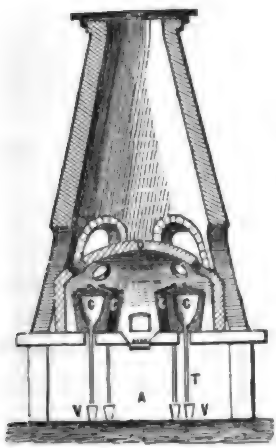
All the ores of zinc should be closely concentrated and

powdered, and the sulphide must be roasted and frequently stirred for from eight to twelve hours, at a well regulated red heat, in a common reverberatory furnace.

Cut 55 represents the reducing furnace, which is built on, and supported by, four walls that enclose the transverse ash-pit, A, and form the two side rooms where the iron receiving vessels, V, V, are seen.*

Under the four crucibles, C, C, C, C, which have holes in their bottoms, four short conical pipes pass down some four inches through the bed-plate, and four long and parallel thin wrought-iron tubes, T, are elevated to jam over their bottom ends, to carry the zinc down into the above named vessels, V, V, V, V. Over and opposite the crucibles, in the sides of the exterior conical chimney, as well as in the side, and on the roof or dome, D, of the interior muffle furnace, are situated as many arched doors and circular holes, for arranging, supplying, and clearing the crucibles, which are generally about four feet high, to hold three hundred pounds of ore.

Cut 55.



The short conical tubes that lie under the crucibles are smeared with a rather thick wash of clay, so that they may be both tightened under them, and in the holes through the furnace.

The holes in the bottoms of the crucibles having been first covered with pieces, or stopped with plugs, of dry wood, one measure of coarse coke or charcoal is laid equally over the bottom of each crucible, then a measure of fine coke or charcoal, and then four measures of the prepared ore—three hundred pounds—is placed thereon, and on it four measures of coke or charcoal.

The whole four pots being charged in a similar manner, and their covers closely luted on, the outside openings in the furnace and chimney may be closed with bricks, and the fire

* For better exposure of the condensing pipes and receiving dishes, only the two outside supporting walls are shown.

lighted in the furnace. The fire should be gradually increased, when the mouths of the short conical pipes which descend and protrude through the bottom will indicate when the long condensing pipes should be attached.

The flame is first a dull brown, which gradually changes and brightens until it becomes of a bright blue color, when the long and thin wrought-iron pipes should be dipped in the wash of clay, and attached to the short conical pipes in a gas-tight manner, by simultaneous twisting and elevating motions.

The volatile oxide passes down and condenses in the tubes, to fall into the receiving vessels, V, V, V, V.

In this furnace, five such charges of ore can be passed through in a fortnight; so that where large quantities have to be smelted, many furnaces must be used.

About twenty-five tons of coal are required for the reduction of one ton of zinc, the total costs being about £20 for each ton of zinc. It is necessary that the heat should be gradually increased by careful management of the fires.

Three men are required for each furnace, as continual attendance is required to keep proper heat, to see that no leakage occurs, and that the discharge pipes are not choked, which will frequently happen unless cleared effectually by a bar of iron; sometimes a hot bar is required to melt down the accumulation of zinc from the small end of the upper pipe.

After upwards of sixty hours have passed away, when the zinc falls but in occasional drops from the tube, the fire may be subdued or withdrawn, and the contents of the crucibles be removed by passage down through their bottoms, to make room for the repetition of the charge.

These crucibles may be made at the smelting works, in the following manner, from a mixture of *best* Stourbridge clay, 1040 pounds; *second-best*, 750 pounds; old pots, 1310 pounds. This will be sufficient for four pots.

A bottomless tub of wood is used for moulding these pots, which is similar in interior shape to the exterior of the crucible. This tub is divided vertically into three sections, and surrounded by two or more hoops of iron, during the ramming up of the crucible. The above ingredients are pulverized, intimately mixed, and so moistened that they may be formed in a supple, yet retentive, solid manner.

The bottom is first formed, then the sides are built up in a rather intermittent manner, from time to time, using suitable local moulds, to favor the ramming, etc., by wooden mallets, and placing moistened rags upon the top, to prevent it from becoming too dry for the adhesion to the next additions.

These crucibles should be allowed sufficient time to dry, be kept in a warm place to expel water, and should not be used for a considerable time afterwards. When first used, the fires should be very gradually increased; and if required to replace another in a hot furnace, it should be first made red hot in a separate fire, and transferred to the furnace by large and suitable tongs, which should have an iron cross-axle attached to its rivet under the middle, so that a pair of wheels may be employed for more convenient and safer conveyance to its place in the furnace, through arched openings that are made for this purpose in the sides of the inside dome or furnace, which are also opposite the outside doorways.

The agglutinated lumps of metal may be taken from the several vessels, and melted in cast-iron pots, during continual stirring and skimming; the metal poured into suitable moulds for marketable ingots, and the dross re-treated with the succeeding charges of ore.

THE SILESIAN PROCESS FOR THE EXTRACTION OF ZINC

Differs but little in principle from the process already described for the volatilization and reduction of mercury, by retorts.

The retorts are made of an equal mixture of Stourbridge clay and old pots, finely pulverized, and moulded into cylindrical form, solid at the back end, and having a hole at the front end, for charging the ore, removing its residual debris, and conveyance of the sublimed zinc, through suitably tapered jointed pipes, to the receiving vessels without, as in the English method just described.

THE BELGIAN PROCESS FOR THE EXTRACTION OF ZINC.

This, like the Silesian, is effected in retorts; but, instead of one, as many as seventy-eight retorts have been used in one furnace, which ran across a narrow vertical flue or chimney, immediately above the fire-place.

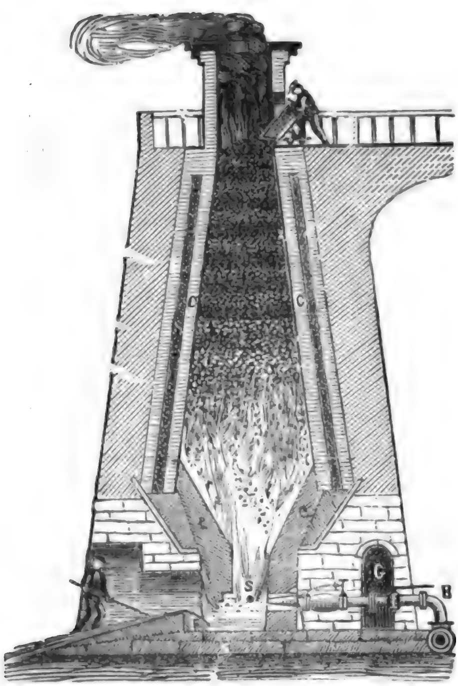
The retorts rest at the back, on as many steps in the wall; descend towards the front at an angle of about eight degrees from the horizontal; and discharge into condensing tubes, as before.

In European practice, with cheap attendant labor, the zinc ores can only be profitably reduced where coal can also be obtained at about the value of $3 per ton; so it is clear that unless some peculiarly isolated local demand shall arise, it will not be advisable to smelt the ores of zinc here.

THE SMELTING OF IRON IN CUPOLA FURNACE, UNDER ARTIFICIAL BLAST.

In the future mining of the vast interior of this country, it will be frequently advantageous to smelt iron for supplying the local iron founders of large mining districts, and sometimes for the more economical working of large and lasting mines, which may then have the heavier wearing parts of their machinery substituted when required, to save the heavy costs for transportation.

Cut 56.



Cut 56 represents a section of the most common and convenient furnace for smelting the various available iron ores.

A strong, square bed of stone is first laid, of about twenty feet in diameter; the centre should be a good fire-rock, and drainage channels should be left beneath, to pass off any moture.

The furnace is drawn to shape; the total height may be fifty feet; the greatest internal diameter at the bottom of the upper round cone, sixteen feet; and the diameter of the underlying square crucible, three feet at the blast-holes.

The properly shaped fire-stone, F, should be placed to form the front of the crucible, with the stones for the sides and back as high as the blast-holes, which generally stand about from two feet to two feet six inches from the bottom. The crucible part, S, is then reared up as shown, and flared outwards to form the bosh, *c, c;* this is at the same time surrounded by the adjoining shell and full-sized outer wall, which is built of strong material, and brought to a dead level at this particular height, to form the bed for the upper cones or double shafts; whilst four channels or doorways are left in its lower part (for front tapping-hole, where the furnace-man is seen with the tapping-bar), for the two *side blast pipes* and the *back blast pipe* (as shown with its governor at B).

The arched gangway, G, is made to pass a little more than half round the back of the furnace, to provide room for the blast pipes and the workmen.

Upon this strong, square prism of bed-work the two circular cones, C, are built, the one being a few inches larger than the other, so that sand may be placed between, to permit expansion and contraction of the inner cone, and to allow greater facility during repairs.

At the top of this is seen a walled terrace and railway for supplying the furnace, which explains itself at sight.

Such furnaces may be worked more conveniently when placed at the foot of a hill, as the road can be made to run at a more convenient level for supplying the furnace.

For the last few years, hot blast has been used, which reduces faster and much cheaper, although the iron is not of such good quality.

The air is forced through chambers or pipes, where it is warmed to about 600° by the wasted heat from the furnace, or by a separate fire.

It is said that, in Scotland alone, two millions of tons are saved every year, by this simple means.

There is another very important advantage gained by the

use of hot blast, which is that ordinary coal may be used, as well as coke and charcoal.

About 6000 cubic feet of air is forced into one of these furnaces per minute, which is four times the weight of ore; so that the difference of temperature is enormously favorable for ease, speed, and economy.

As to the quality of iron, it may be more owing to the use of coal that contains sulphur, phosphorus, etc., instead of coke or charcoal, than to the hot or cold blasts.

Large blowing cylinders are used in England to supply the air, the steam being sometimes applied at the one end of the lever, whilst the air cylinder lies under the other end; at other times, the steam is worked under a lesser radius than the air cylinder, at the same end; or immediately over, in a direct manner.

Powerful fans are sometimes used, which are driven by belts; and on the continent of Europe, for smaller furnaces, the French water-blower, called the "trompe." At other places, a pair of small and very fast short-stroke engines are directly attached to two cranks on the axle of the fan itself.

The size of nozzle depends on the pressure, as governed by the particular machine used.

The carbonate, magnetic, specular, brown hematite, and bog iron ores, are those used for smelting into metallic iron, which are variously fluxed, according to the nature and quantity of the associated gangue.

Nearly all of the iron smelted in England is derived from layers and nodules found in the coal measures. It is essentially carbonate of iron; but it is more or less mixed with argillaceous earths and clay.

Brown hematite stands next in importance, amongst the English smelters.

The magnetic iron ore is smelted in Russia, Norway, and Sweden, and produces excellent iron.

In Western Europe, the spathic, and in Prussia, the bog ores, are mostly reduced.

In the United States of America, the carbonates of the coal measures, and all of the other ores, abound, and are therefore beneficiated for metal, as either may be circumstantially advantageous.

The ores are broken to suitable size, and roasted in heaps (unless naturally free from volatile deleterious ingredients); then fluxed and charged in the smelting furnace in the following manner.

The furnace should be gradually dried and warmed by a steadily increasing heat, until it becomes thoroughly hot, which will require at least several days, to ensure safety against the settling and freezing of the metal around and upon the bottom of the crucible part of the furnace.

In smelting the carbonate of iron, as mixed with argillaceous earths and clays, after the furnace has been nearly filled with either charcoal, coal, or coke, and supplied with full blast, 1000 pounds of ore may be added, 1000 pounds of fuel, and 200 pounds of limestone; of course, if the latter is naturally present, it need not be added. If there is no silica present, a quantity equal to that of the lime may be advantageously supplied, to form a better slag, and lessen the destruction of the furnace.

These fluxes must be sometimes increased to as much as twenty-five per cent., to suit the more refractory varying ores.

To aid in the decomposition of the sulphurous ores, and replacing them into harmless forms, some smelters charge about from one to one and a half per cent. of salt, which is either mixed with the ore itself, or blown in with the blast.

As the contents of the furnace descend, other charges may be supplied in similar manner; and in about from forty to fifty hours, the first metal may be tapped into suitable sand moulds, to form the well known "pig iron.

The smelting being then continuous, the crucible will be again and again filled and emptied of its metal during the periods of from eight to twelve hours, in the same manner; whilst the floating slag will be as often passed away over the front dam-stone, and which may be cast into moulds to form large bricks for building purposes.

The best proofs of success are fluidity of the metal, which, when cold, should be of dark gray color, and fracturing with difficulty to a coarse granular texture; being opposite to bad metal, which flows sluggishly, is brittle, and exposes an almost grainless, white fracture.

The quality of each is marked by No. 1, No. 2, No. 3, and

No. 4 pig iron, where the first and last represent the above extremes.

Thus, No. 1 is a fusible and soft, dark gray, coarse granular iron.

No. 2 is of a lighter gray and finer grained strong iron.

No. 3 is mottled into white net-work lines, hard, and more brittle.

No. 4 is quite white, very hard, and too brittle for strength.

Sulphur and phosphorus are the most objectionablė ingredients, for both render the iron brittle.

The slag should be of an even, light color; for if dark and heavy, the iron has not been fully reduced, from insufficient coal and time; if streaks of a green color traverse the black, silicate of iron has been formed, and therefore more lime should be added.

SMELTING OF CAST IRON IN SMALL CUPOLA FURNACES, TO SUPPLY THE VARIOUSLY SHAPED CASTINGS FOR MINING PURPOSES.

To provide for extreme cases, in distant sections, and to replace the worn parts, such as shoes and dies, pestles, bottoms, etc., a small and very plain cupola furnace may be made for use on the mine, as follows.

Build a hollow cylinder, with bricks, about eight feet high and two and a half feet internal diameter, on a three feet cube of solid bed-stone.

On the front and at the bottom of the cylinder, an arched opening of about ten inches should be made therein, to facilitate the lining up and cleaning out the furnace. At the back side of this cylinder, and about fourteen inches from its bottom, a round blast-hole of five inches diameter must be also left, with another similar hole six inches above it.

This cupola, being now tightly lined with about four inches of fire-resisting sand and clay, is ready for being slowly dried and used for the casting of pieces of about 1000 pounds' weight.

A common fan machine, of two feet diameter, may be now made, of wooden shell, with iron axle and blades, fixed just opposite, and a few feet back from, the blast-hole, to be

worked by two horses, by a small over-shot, or larger under-shot water-wheel, or the steam engine.

The above named articles may be cast in suitable iron moulds or "chills." *Skilled moulders in sand* will be unnecessary, and the smelting is not difficult.

The thoroughly dried furnace is filled with charcoal or coke, and after the front opening has been stopped up with fine sand, and secured by a front plate of iron, excepting just where the small tapping hole is left therein, the full blast is continued for about an hour, and then (the furnace being full of fuel) a charge of two hundred pounds of new and old cast iron, broken into small pieces, is thrown on, and allowed to warm and descend upon the burning fuel, until another supply of coke or charcoal can be made, and still another charge of iron.

Thus, layer on layer is supplied, until sufficient metal has been melted for the day's run.

As soon as the molten metal runs freely through the tap-hole, in white-hot, molten state, this hole may be closed by a piece of rounded, moistened clay, placed on the end of a long, round pole that is kept for that purpose, which effectually stops the metal and the hole, when placed under the pressure of gentle thrust, during a suitable twist.

Care must be taken that the furnace is charged regularly, and that the contents descend equally, so that chambers shall not be formed, to occasion sudden drops of the cold upper charges to the lower region of the furnace; and also that the blast-hole is clear and the opposing fire bright.

As soon as the pool of metal appears at or near the blast-hole, it may be drawn off by a sharp-pointed tapping bar, in kettles, for transferrence into moulds, or it may be conveyed directly into the moulds, by suitable sand-lined launders.

The metal may be stopped off, at any moment, by the judicious insertion of the clay "pod" or plug. Several spare plugs should be kept, in case the first fails to stop.

THE EUROPEAN OR "CONTINENTAL" METHOD FOR SMELTING COPPER ORES, BY CUPOLA,

Will not be so available for this country as that described, by reverberatory furnace, called the "English Method;" and

as it will be explained, so far as is necessary, when treating of the extraction of silver from copper, etc., by the Ziervogel chemical method, those whom it may concern are referred forward to that subject, in Chapter V of this Section.

The cupola furnace shown by Cut 57, *at page* 581, *will, however, answer very well for the more speedy smelting of copper ores into "marketable matte," where charcoal can be obtained cheaper than coal or coke.*

SMELTING OF THE OXIDE AND CARBONATE OF LEAD IN CUPOLA FURNACE.

It will be frequently more advantageous to smelt some of the lead ores in this way, when wood is plentiful, than by the manner described at page 556; more particularly so, when good, economical, steady, and convenient water-power can be obtained for blowing air to the fire by fan machine.

The shape of the furnace, position and size of blast pipes, and manner of charging, influence the results more than is generally imagined; and the following scaled and figured cut will probably afford as good a general-purpose cupola furnace as can be made.

With such a furnace, we smelted ores at Ætna and Oreana, in Humboldt County, Nevada, on two different occasions, that had resisted all other means; for, in the former case, five tons of ore had to be passed through to make one of metal: the ore being associated with a highly feldspathic gangue, whilst the produced metal was of an equally troublesome alloy, being at least half antimony.

In the second instance (the smelter acting under my instructions), three tons of ore, of an equally stubborn constitution, were required to produce one ton of similar metal.

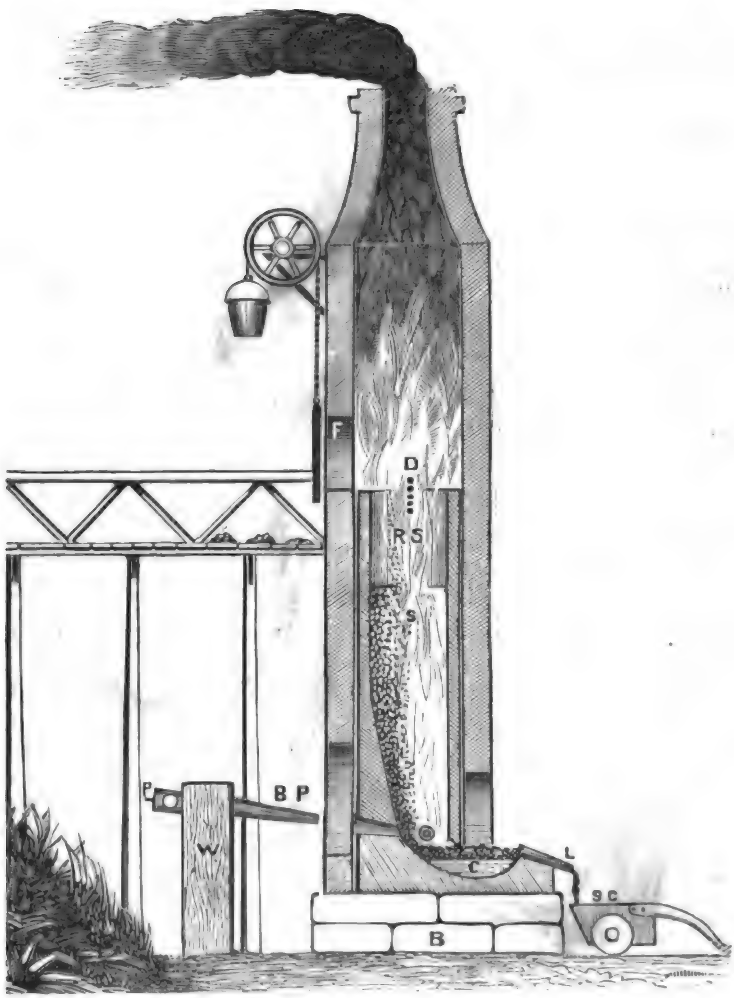
The ores, however, should have been hand-picked, or in some way concentrated, to render the smelting less difficult, and more economical.

Cut 57 represents this cupola furnace, as built at the base of a hill-side, with roadway, feeding track, and feed-hole, F, which is stopped at pleasure by the balanced door, so that the heat may be retained, and the draught increased during the intervals when the ore is not being charged.

In these instances, pine charcoal was used for fuel, which will be the general reducing agent in the interior of this country, for smelting by cupola.

On the square bed of strong granite stone, B, the horizon-

Cut 57.



tally sectioned, oblong crucible, C, is built, of fire-rock, or fire-bricks, and shaped as shown in the section, to the height of the blast pipes, B P, and just to the full width of the square furnace as marked at S, which rises, of the same shape and

area, to the round part, R S, that then continues in cylindrical form to the feeding hole, F.

A screen (of transverse wrought-iron bars) is shown at D, which was placed to aid the workmen in charging; as when the mixed ore was thrown against it, the coarse and the larger part fell down on the first or back half, whilst the smaller passed forward on the comparatively clean charcoal.

By this simple device, the heated gases and flames were encouraged to pass through the unchoked interstices of the coarse, whilst the finer pieces were scattered sufficiently throughout the living charcoal in front to be promptly and thoroughly reduced, without clogging the furnace in the slightest degree.

So, also, as the charge descended from the smaller and round upper shaft, R S, to the square shaft, S, it *exposed and spread its crescent wings;* and therefore, being completely surrounded in the *active corner fires* of the square shaft, it was much more speedily reduced than would have been the case if the excessive quantity of gangue had been crowded into the similarly sized and shaped (all round, or all square) furnace.

W, is one of the three large and square wood pipes, which arise from the larger horizontal main pipe, that lies buried from the fan blast to these several supply points.

In and through these vertical wood pipes, the iron blast pipes, B P, were closely fitted into the two guide holes on the back and front, and which descended just as much as shown, to serve the three purposes, of affording downward pressure upon the slag, to aid in forcing the infusible slags through the discharge opening; to prevent the metal, when at the height of the blast hole, from running back into the blast pipe; and by its own weight in that direction, to keep it steady to its work, just where placed.

It will be also seen by the illustration of this blast pipe (B P)—which, excepting just a small bar-hole for examination and clearance of slag, is closed at the back end—that it is now entirely withdrawn from the furnace, and that the blast is completely shut off, as the round holes through which the air should pass are entirely without the vertical supply pipe, W. This economizes air, and therefore the engine will, by traveling faster whilst the one blast-hole is

being cleared, force more air into the furnace through the others. It need not be withdrawn for ordinary clearance, as a bar may be passed in through the plug-hole (now stopped by the plug, P), for this purpose; for more extensive clearance, it can be partially withdrawn, to keep the blast still on; and when more room is required for working large bars, it can be drawn still further back, to shut the blast off entirely.

Having built the furnace and appurtenances in the manner described, place in its bottom some dry sticks of wood, and fill it to mid-height with larger pieces.

Kindle, and allow it to burn as slowly as possible (by covering the furnace over, and stopping the openings, after the manner of making charcoal, to prevent the current of air that would otherwise consume the wood), for twenty-four hours; after which, fill, and keep it full, with charcoal, and allow it to burn for eighteen hours, with a throttled natural draught; then for six hours under a moderate blast, until you are sure that the furnace has been thoroughly heated throughout, and that the bottom will not have a chilling effect on the molten metal and slag.

Next, being sure that the furnace is quite full of *living charcoal fire*, charge full charges—*not part charges*—of mineral and fluxes, as follows. Regarding flux, we will consider carbonate of lime, of good quality, which should effervesce strongly, and dissolve almost entirely in the strong acids, to be your most reliable help in smelting ores. I am not so sure of the equal qualities of tuffa, which is plentiful in Nevada, and composed of chloride of sodium, several carbonates, including carbonate of soda: the chloride of sodium is serviceable, but carbonate of soda is in two respects so deleterious, that it should be used with much watchfulness, fear and trembling; for, firstly, it renders quartz very fusible, and would disintegrate any fire-rock that contained quartz, and thus waste the furnace to an unworkable shape, in a short time; and, secondly, it has the power of reducing lead to comparative purity, when mixed with antimony, the latter passing away as sulphide, into a clogging, waxy slag, and oxide of antimony; thus, the antimony that would otherwise alloy with the lead, and increase the quantity of metal tonnage, is wasted.

I therefore advise you to rely on white marble, calc spar, or blue limestone; and do not fail to test it by acid for effervescence and almost *complete* solution.

Break the ore into pieces of the size of chestnuts, and throw away all hard and light pieces, and retain such as contain nothing but lead or iron ores.

Break the carbonate of lime into pieces no larger than beans.

Select the most fusible and brittle slag, which break to the size of chestnuts, and such metallic lumps from former smelting as will cut softly with a knife, and that look metallic; and cast away forever the hard and tough, blue kinds, which will not cut freely with the knife.

You may charge charcoal until the furnace is full, but never less than two bushels (forty pounds); then a half-shovelful of good slag, against the nearest, or back side, of the furnace, by a judicious turn of the shovel; next a shovelful of marble, scattered over all the furnace, as a corresponding layer under the mineral to be smelted; then five shovelfuls (eighty pounds of the ore), which must be thrown against the screen of transverse bars in such a manner that the coarse shall rebound and scatter over the nearer half of the furnace, and the smaller pass through and be distributed over the further half.

The charging may be varied in this respect according to the working of the furnace, which must be closely watched; when working *freely*, a shovelful more may be thrown over the screen, and four against it at the back side.

These separate piles of charcoal, slag, marble, and ores, should be conveniently arranged from the left to the right-hand side of your charging stage—at least the slag, marble, and ores; in such a way, no mistake in charging can arise, without gross indifference; nor errors from improper or unequal mixture of these fluxes in the large heap; it is, moreover, the easier and cheaper way for supplying the material, and works better in smelting.

After charging, the balanced sliding door should be closed, to secure the heat and increase the upward current of air, by this additional chimney.

Close watch should be made, through a hole in the door,

that the charge shall not jam in the furnace, and by proving, by a curved bar, that the last charge has properly descended before another is supplied; as, otherwise, the furnace would be sure to cool and clog, as the cold charge would fall down close over the blast, and solidify accordingly; as the excess of cold air, in a too shallow fire, would chill, instead of fuse, the agglutinated mass.

As the smelting proceeds, the fused mass of ore will descend towards the bottom, and at or about a foot above the blast-holes the metal will be fully reduced, and fall to the bottom of the crucible; whilst the lighter slag will follow in a continuous stream, near to and beside the back wall, and on to the suitably curved bottom, to be urged by its own following weight, and gradually turned towards the front outlet, to flow by way of the lip, L, into the slag car, S C, for more easy conveyance to the waste heap.

The slag should flow freely, in almost continual liquid streams, from the furnace; have glass-like characteristics, but must not contain any shot-like globules of metal, nor highly metalliferous compounds. Its specific gravity may be occasionally tested, approximately near by the hand of the experienced, but better by an actual test; and assays may be made for the purpose of testing the percentage of the thus enclosed escaping metal.

In addition to the foregoing precautions for favoring the smelting of refractory ores, that contain much infusible gangue, it is highly important that the nozzles be kept clear, that the blast pipes be large—not less than three inches in diameter—and that the bottom of the blast pipes shall be at some five or six inches higher level than this slag outlet; so that the slag shall be forced, by *actual pressure*, through the opening, when not sufficiently disposed to depart under more perfect fluidity. As soon as the metal fills the crucible—which may be seen at the lip, by removing the slag—it should be tapped off into a sand-lined crucible, that lies beyond the slag opening, on the other side of the furnace, and be dipped from thence into moulds. for further treatment by calcination, for the sublimation of antimony; or for the oxidation of the lead, and extraction of pure silver, by processes that will be soon described.

The above treatments apply more directly for the oxides and carbonates of lead, both when alone, or associated with antimony.

The following receipts and analysis may be serviceable.

"'Dry bricks' of superior quality are now made in England, of improved material, and by a process said to possess important advantages over others now in use. These bricks are composed of one part of lime to eight or ten parts of sand or burnt clay, and they are found to be ready for use about ten days after pressing, without being burned. It is found that they do not swell, as is ordinarily the case from the slaking tendency of lime when not made according to this method. In the manufacture of mortar for brick-laying, it is also found that great strength and service result from the following proportions of ingredients: water, half a pail, and four pounds of plaster of Paris; these are mixed, and then there are added, in the pan of the edge runner, two or three pails of water, a bushel of lime, and six bushels of sand, the whole being ground together for ten minutes. For a powerful mortar for pointing, water, plaster, and lime as before, with two parts chalk, slaked lime, or whiting, and two parts of sand. For a coarse stuff for plastering, the same ingredients as for mortar, but coarser sand, and only five minutes' grinding. For fine stuff for plastering, water, plaster, and lime as before, a bushel and a half of chalk, and two bushels of fine mashed sand. For rough stucco, the same as for mortar, with four bushels only of sand. Plastering on walls can be done by this process as two-coat work, while ceilings can be floated immediately after the application of the first coat, and set in forty-eight hours. The thorough adaptability of this material for the purposes named is said to be remarkable; and, in regard to the cements, they are very quick setting, and produce a very hard and finely finished surface."

A good fire-stone may be made from an artificial mixture of one part of clay and about two and a half parts of quartz sand, which may be moulded to any desired shape, or cut afterwards.

A still better and more enduring stone may be made by mixing one part of raw clay with two parts of burnt clay and

one and a half of graphite; then moulding into suitable shapes.

A sample of Stourbridge clay, analyzed by Berthier, yielded as follows.

Combined water	10.3
Silica	63.7
Alumina	20.7
Oxide of iron	4.4
	99.1

SMELTING OF THE SULPHURET OF LEAD IN CUPOLA FURNACE, WITH SCRAP IRON.

Add ten pounds of cast iron to the charge, as given in the last example, for the carbonate and oxide, and proceed to smelt as there directed.

See the "Re-actions of Iron with Galena," at page 557.

SMELTING THE ROASTED SULPHURET OF LEAD IN CUPOLA FURNACE.

1. Roast the pulverized ore in the reverberatory furnace, with a gradually increasing and moderate maximum heat, under continual stirring. Then close the doors of the furnace, and increase the heat so as to fuse a portion of the mass into silicates of lead, lime, etc., which, with the remaining sulphide, the sulphate, and oxide, may be then withdrawn and broken in suitable pieces for smelting in cupola.

2. Roast in large (fifty tons), coarse stone heaps, laid over a bottom of wood logs, which are kindled from the centre, to first ascend a central chimney, that it may ignite and roast the whole mass, which is surrounded and covered with previously roasted fine ore, to retain and direct the heat for ascension through the whole heap. Concave dishes may be placed on the top, to collect the volatilized sulphur as it condenses therein.

This burning generally lasts for some eighteen or twenty weeks, and is much facilitated when sulphuret of iron is also present in quantity.

The ores which have been roasted by either of these means may be broken to the size of hazel-nuts, and smelted in the cupola furnace, as by the last two manipulations, but in

charges composed of two hundred pounds of roasted ore, sixty pounds of very siliceous slags, and if you have them, three pounds of the oxide of lead, or the calcareous fragments of old cupel bottoms, which contain it.

The foregoing rélative quantities of ore and fluxes should be considered to apply but in a general way, and therefore they must be made to vary for different proportionate mixtures and constitutional forms of minerals and matrices, as ascertained by analysis and forethought, or by varied subsequent trials.

Hot blast will be found superlatively effective for either of these means, and may be obtained by utilizing the departing heat from the furnace, as for iron smelting, and as the fumes of oxide should be caught, it may be simultaneously accomplished.

The tuyers may be also surrounded with water, to render them more enduring.

Should you require to consult others in the matters of treatment, the average should be prepared with great carefulness from large assortments, diminished in the systematic manner described in the chapter for the "Preparation of Average Sample," at page 119.

THE MOST READY EXTEMPORE MEANS FOR SMELTING SMALLER QUANTITIES OF THE CLOSELY CONCENTRATED LEAD ORES,

Are the Scotch and the American hearths.

The Scotch hearth is a very short and small cupola furnace, which is supplied with a strong blast from the back, as the others. The short shaft of the furnace is first filled with peat, and ignited; on this is thrown a few shovelfuls of coal, and when the blast has produced sufficient general heat, some of the ore or its matte is thrown on, and smelted down into the bottom. This slag is then taken out on an exterior front stone, that slopes towards and over an iron basin, and thoroughly rolled or kneaded, the lighter portion is thrown away, whilst the heavy is returned to the furnace for repetition with the next charge, and so repeated until its lead is reduced to fall into the iron kettle that lies under the outer kneading stone.

A good worker can smelt about three tons of metal per

day, in such a furnace; but, as it is expensive in fuel, and requires considerable labor and skill, an illustration will be of no value, for any one of the larger methods are preferable.

The American hearth is also a short cupola, blast furnace, differing from the Scotch in having an easy and effectual means for warming the blast.

The blast enters at the one side, near the front of the furnace, and after passing through a chamber around the back of the hot furnace, it passes out through the other side, and then right into the furnace through the blast pipe at the back, in the usual manner.

It may be made of cast iron, and so far as the hot blast is concerned, it may be regarded as an improvement upon the Scotch hearth.

CALCINATION OF IMPURE LEAD, TO RID IT FROM MORE VOLATILE METALS, MECHANICAL DROSS, ETC., TO OBTAIN MORE MARKETABLE LEAD; OR FOR THE SUBSEQUENT EXTRACTION OF SILVER BY CUPELLATION; BY THE PATTINSON, OR THE ZINC PROCESSES.

The various alloys of lead with antimony, zinc, etc., etc., may be readily calcined in a furnace similar to Cut 45, page 498; and the objectionable, more volatile metals be removed by volatilization and oxidation, into a dross that can be removed from the surface by a rake.

For this purpose, a cast-iron, flat-bottomed pan will be necessary, of about from eight to ten feet long, by five feet wide and nine inches deep, which should lie evenly over the whole hearth, on a bottom of sand. Although it is advisable to have this pan as large as possible, because of the greater quantity that can be treated by the fuel, this size should not be exceeded, for they are then likely to fracture from unequal contraction.

For this safety, *soft iron* should be also used by the founder, the mould should be inclined, and the metal be poured therein from the lower end, to flow through the upper "gate," or "runner-way," for some time after the mould is full, that the scoriæ may pass out, to leave solid metal behind.

The top of the fire-bridge should be about six inches above

the top of the pan, and the roof of the furnace may be from ten to twelve inches above the pan, so that the oxygen of the heated air may pass immediately over the molten metal.

The charge may be from six to eight tons, and the time required will, of course, vary from ten to thirty hours, according to the kind and quantity of impurity that is mixed therewith. The appearance of the dross, as it is scraped off from the hot bath, will give you notice when the lead is approaching to purity, when samples of metal may be drawn and bruised to a very thin disk, to test it fully as to its peculiar tenacity and freedom from cracks.

It may now be tapped off into a large kettle, and ladled into moulds, for convenient ingots for market or further treatment for silver. Sometimes this kettle has a fire under it, so that the metal can be previously melted, and ladled into the large furnace, for immediate calcination.

The oxidized metals may be caught in large chambers in the flue, or in the hill-side chimney, as previously described.

CUPELLATION OF ARGENTIFEROUS OR AURIFEROUS LEAD.

There is but little difference in the first principles of cupellation by any method that has been devised since Scriptural times; for it is still accomplished on some porous hearth, as wood, bone ash, marl, etc.; so that a part of the base oxides shall enter therein in fluid state, whilst the remainder is volatilized as dry oxide, to pass off by way of the chimney.

There are, however, important differences in manner of oxidation, which are derived from mechanical facilities; and perhaps, for this end, the English method will be found generally preferable, as the trifling extra cost is more than compensated for by greater comfort and safety in use.

Cut 58 represents the section and plan of the furnace, where A is the ash-pit, F the fire, C H the cupel hearth, W its supporting wagon, B the blast hole, D the discharge lip, F F the flues, and S the smoke-stack, which should be made of but moderate height, as the heat must not be too great, nor the draught so strong as to prevent the effectual transverse play of the especial oxidizing blast.

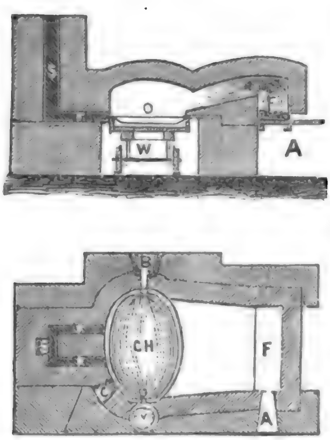
The carriage is made for the direct purpose of supporting

and placing the cupel hearth in position, and removing it when necessary, for a new one. The hearth should be either fixed on central trunnions, or on screws, that it may be tipped towards the discharge when it will be found necessary.

It will be seen by Cut 59 that this cupel frame is merely an elliptical *ring* of angle iron, crossed by *bars* of iron, which serve to sustain the bone ash that forms the hearth.

The most convenient and generally used ash is made from bones, which are first slowly burned in a suitable kiln, until all volatile and carbonaceous matters have been passed away; then they are pulverized in dry condition, and passed through a wire sieve of about twenty holes to the inch.

Cut 58.

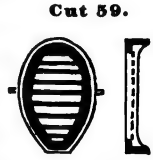


It is imperatively necessary that dry crushing be used, so as to keep the edges ragged and tooth-like, that the ash may lock together more effectually.

Sufficient water may now be added, in which a very little carbonate of potash is dissolved, so that the ash can be made to jam together under a suitably shaped wooden beater, and be also smoothed by a trowel, to form the concavity for the metal.

The ash is too moist when the water is made to appear on the surface after this beating, and too dry when it will not hold together.

Cut 59.



Being thus formed to shape, it should be slowly dried; and to facilitate this end, two or three frames should be provided, and a suitable crane to hoist the finished supports to or from their drying places.

It will be much more convenient to have *two carriages*, and two *especial drying stoves* (like those used by iron founders for drying cores), so that the one carriage and hearth can be removed either in or out from one or the other stove, as required, the one being thus dried whilst the other is in use.

The railway must, of course, pass under the furnace, in a

straight line from the one drying place to the other, so that each, having its own carriage, will provide a new cupel immediately the other is withdrawn.

To perform the process of cupellation, the hearth is first warmed slowly to redness; then the metal, which should be first melted in an outside kettle by another fire, is introduced through the appropriate charging hole, C, and when it becomes of a clear molten state, and nearly fills the cupel, the side blast is played thereon, which immediately oxidizes the surface of the pool, and passes waves of the fluid oxide before the blast, towards and over the discharge lip, to fall into the underlying vessel, V.

This discharge of oxide is regulated by charging more metal, and tipping the cupel by appropriately fixed wedges, racks, or screws, but better by a worm motion applied at its side, to move it at pleasure, on central pivots or trunnions, like the motion of a heavy gun, or a crane kettle.

Moderately rich and rich bullion, from $400 upwards, is best adapted for this mode of refining; whilst the very base bullion may be beneficiated more economically and effectually by either the zinc or the Pattinson process.

When sufficient metal has been added, and the cupellation has been carried sufficiently far to enrich the remainder to some $4000 per ton, it is run into ingot moulds, for further treatment.

A new cupel is run into the furnace, when, after it is slowly heated to redness, about five hundred pounds of the rich ingots are melted in the outside kettle, and charged thereon; a strong blast is applied, when, the cupel being inclined, a copious stream of litharge passes over the lip; more of the rich lead is added, until some five hundred pounds of silver are known to be contained in the alloy, when the whole is allowed to purify without further addition; towards the end of this stage, peculiar and beautiful rainbow colors will play over the surface of the metallic bath, as the last base oxide passes away, until the universal silver surface appears, of mirror-like lustre, when the blast must be stopped, and the fire subdued, so that the silver shall cool slowly, to prevent loss by spurting, caused by its departing oxygen.

It may be now completely refined on a clean cupel, or in plumbago crucibles.

The last oxide (litharge), as it grows richer towards the end, is again reduced, and re-cupelled for its silver.

When silver and gold are both present in profitable quantities, cupellation will, of course, obtain both, and it is therefore the best mode of extraction.

Other methods are used on the large scale, for rich lead, similar to those miniature modes described under the subheading for cupelling and refining gold and silver, in Chapter VII, on assaying, at page 214; and the following means have been generally adopted on the continent of Europe.

"REFINING SILVER UPON POROUS HEARTHS.

"Silver may be refined in a movable hearth, and in a furnace similar to that employed in the English cupellation, but smaller, and containing no apparatus for throwing air upon the fused metal, or in a furnace with fixed hearth and movable vault; or beneath a muffle. The first named plan is in use in England and in various parts of the continent; the second is adopted in different parts of Germany; and the last named is especially employed for treating the silver produced in the Upper Hartz, where about 21,000 pounds are annually refined.

"The silver from the various royal furnaces is collected at the old mint at Clausthal, and there refined; six days in the month being set apart for that purpose.

"The *tests*, or small hearths upon which the fusion is performed, are prepared by heaping leached wood-ashes into an iron form, then cutting a hollow in the mass about one foot in diameter, and three to four inches deep. These are properly dried, and when about to be used, are set in a furnace consisting of a bench of mason-work, with side walls to retain the fuel that is piled upon it. A fire-clay muffle is placed over this *test* or cupel, and so arranged that the attendant may have access to the interior, and a stream of air may pass over the surface of the test. A strong fire of charcoal is now made around the exterior surface of this muffle, and the whole apparatus soon brought to a high heat. The silver, as it comes from the furnaces, is broken into fragments, and placed in the crucible to the amount of forty to fifty pounds, the door of the muffle closed, and the metal allowed to fuse, which requires two hours. The door is now opened, and the metal stirred with an iron bar, and thus subjected in all its parts to the oxidizing influence of the air. This stirring is repeated several times during a period of two hours, at the end of which time, the refining is usually concluded.

"The surface of the metal is at first quite dull, from the oxides (chiefly that of lead) which swim upon it; but these are gradually cleared away and absorbed by the porous ash of the cupel, and at length the surface assumes a mirror-like brilliancy. The proper degree of fineness having been reached, the silver is allowed to cool gradually, and when almost hardened, the surface is kept open by stirring, that loss by the violent escape of gas may not take place. Water is now thrown upon it, and after becoming quite solid, the mass is taken out of the muffle, hammered into a convenient shape upon an anvil, the particles of impurities adhering to it cleaned away, and it is then ready to be transported to the mint.

"The silver thus obtained is nearly pure, being .9948 to .9965 fine. During the five years between 1854–5 and 1858–9, 94.408 pounds of fine silver were produced from 101.559 pounds of silver of cupellation, indicating a loss of 7.05 per cent. in the process of refining. The cost of accomplishing this operation is about 2½ *d.* per pound.

"At Freiberg, in Saxony, where the yearly production of silver is about 62,000 pounds, the refining is performed in reverberatory furnaces.

"The hearth is made of marl, and is large enough to hold 10 cwt. at a time. The vault above is made movable, so that the workmen may have every opportunity of making the hearth perfect.

"The mass of the hearth being well dried, the above mentioned amount of silver is charged, and a good coal fire kept up for two or three hours, at the end of which period, the silver is found fused.

"A current of air is now directed upon it, which sets it in motion, and exposes all parts to an oxidizing influence; the impurities, which consist chiefly of lead, are thus fused, and absorbed by the porous hearth. Assays are taken from time to time, and when the silver shows a silky lustre and fine texture, which usually occurs in one and a half to two hours, it is quickly taken out of the furnace by means of iron ladles, and poured into iron moulds. The ingots thus formed, which weigh about eighteen pounds, are taken to the Saxon mint."—*Dr. R. H. Lamborn.*

PARKES' ZINC PROCESS, FOR EXTRACTING SILVER.

This process is based on the fact that when a hot molten alloy of silver and lead has zinc added thereto, the silver, having a greater affinity or preference for the zinc, will leave the lead to associate therewith, when they can be separated by simple skimming, and subsequent parting of the silver from the comparatively small quantity of zinc.

It may be best explained by dividing it into five stages, as follows.

1. About five or six tons of lead, of low per thousandths of silver, is first melted in an iron pot, by an underlying fire, the heat from which is largely distributed around its surface, by suitably arranged flues. To this you may add one per cent. of melted zinc, and after stirring industriously for two hours, subdue the fire, so that the molten metal may form the argentiferous zinc crust upon its surface.

2. This crust must then be removed with a ladle (so perforated that the lead may be drained through, whilst the crust remains on top), for the extraction of the silver which it contains. The remaining desilverized lead may be now also purified from any little zinc, etc., by calcination in reverberatory furnace, in the manner already described.

3. These zinc skimmings should be heated in diagonal retorts, to release the lead (which generally contains from $800 to $1200 per ton of silver), and must be cupelled after methods described.

4. That remaining in the retort may be further prepared and beneficiated by the method for the distillation of zinc.

5. The resultant sponge of alloy, which contains most of the silver, with other metals, may be mixed with but just sufficient lead, and cupelled for its silver.

The loss of lead is very little (from one to one and a half per cent.), the process is simple, and very available for metal which contains less than $20 per ton.

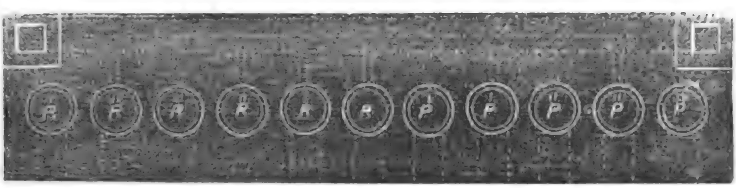
PATTINSON'S CRYSTALLIZATION PROCESS, FOR THE PARTIAL EXTRACTION OF PURE LEAD, TO ENRICH THE REMAINING ARGENTIFEROUS ALLOY.

Mr. Hugh Lee Pattinson, of Newcastle-on-Tyne, England, introduced this system in the year 1829, for the profitable extraction of silver from lead that contained much less than was up to that time considered possible.

Its great field commences where the old method of cupellation ceases to be available; and as but one and a half per cent. of the lead is said to be wasted during the separation, it is more eminently advantageous for economy of lead.

Most of the commercial leads held at that time no less than teens of dollars, and as $4 per ton could be profitably extracted by his process, it had, and still has, an immense amount of work to accomplish.

Cut 60.



The accompanying illustration (Cut 60) shows the plan of the whole number of cast-iron melting pots, which should not be less than nine, and be sufficiently large to hold from three to seven tons of metal.

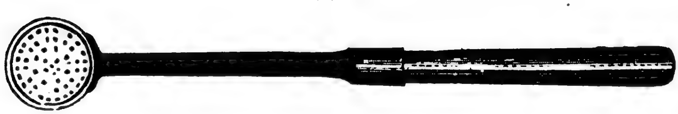
The several pots, marked A and B, are embedded in masonry, in such a manner that their separate fires and flues (as shown by the dotted lines) may afford a large heating surface. These flues communicate with the chimneys seen at the end corners, and each fire should have a regulating damper. It has been well described as follows

METHOD OF MANIPULATION.

"If lead having ten ounces of silver to the ton is to be treated, the kettle, P, is selected for commencing the operation, and say 140 cwt. are placed in it, and heated rapidly until fused. The heat is continued until the metal is raised to a temperature somewhat higher than that necessary to give it complete fluidity. The fire is then put out, and the mass in the pot partly cooled by throwing water upon it. This must, however, be done with the utmost caution, since the water may become so surrounded by fused lead that the sudden formation of steam will lead to explosions dangerous to the men employed, and leading to a loss of metal. If a little more time is allowed, the cooling will take place without the necessity for the employment of water.

"The mass begins to cool at the surface and along the sides of the kettle, and the crusts thus formed are carefully detached by means of a bar, and thrown back into the fluid, the cooling being thus caused to go on regularly. The stirring is at the same time continued regularly, that the crystals may form as free as possible from silver.

Cut 61.



"The ladle represented by Cut 61 is employed for lifting out the crystals. The lower part is formed of iron, and the upper of wood, that it may be more conveniently handled. It is kept warm, and before being used, is plunged several times into the fused metal, that it may assume entirely the same temperature.

"When the crystals have formed in a sufficiently large quantity, a ladleful is raised above the surface, and allowed to drain a few moments, and then, by a skillful movement of the workman, thrown into the neighboring kettle, P′. The ladle is then re-warmed, and cleaned of the lead hanging to it, and the process repeated until about 80 cwt. are thrown into the kettle, P′. This portion is found to contain about five ounces of silver to the ton, or fifty per cent. less

than the original lead. An additional 20 cwt. is now ladled out, containing about ten ounces to the ton, and thrown into R. The 40 cwt. now remaining in P contain twenty ounces to the ton, and this is transported by means of a ladle without perforations to the kettle, R′.

"The kettle, P, is now ready to be filled again, and the same course pursued. When the kettle, P′, is filled with lead holding five ounces, it is allowed to cool and crystallize in its turn, and 80 cwt. of crystals are ladled from it, with two and a half ounces of silver, and thrown into P″; 20 cwt., with five ounces, are laid aside, to be returned to P′; and the remaining 40 cwt., with ten ounces, are transported to P or R. P″ is treated in the same way when full: 80 cwt., with one and a fourth ounces, are thrown into the kettle, P‴; 20 cwt., with two and a half ounces, are laid aside and given back to P″; and the remaining 40 cwt., with five ounces, are passed to P′. The lead in P‴, with one and a fourth ounces to the ton, is either considered sufficiently free from silver to enter commerce, and is simply fused and moulded for market, or it is made still poorer in silver, even to twelve pennyweights per ton, but in many furnaces it will not pay to descend to this limit.

"At the opposite end of the row of pots, the rich lead is at the same time being treated. When R′ has been filled with lead holding twenty ounces, it is fused, and then allowed to crystallize: 80 cwt. are ladled from it into R, with ten ounces of silver to the ton; 20 cwt., with twenty ounces, are laid aside, to be treated again in R′; and 40 cwt. go into R″, carrying with it silver to the amount of forty ounces to the ton. When R″ is full, it is subjected to the same treatment, and R‴ receives 40 cwt., with eighty ounces to the ton. The contents of R‴ are crystallized, and produce for R⁗ lead with one hundred and sixty ounces to the ton, which, in its turn, is treated in the same way, and finally 40 cwt., with three hundred and twenty ounces to the ton, is obtained in R′′′′′. In some furnaces, concentration is carried still higher, and lead with six hundred and forty ounces is obtained. This is ready for the cupelling furnace, and is moulded into blocks and transported to that apparatus."—*Dr. R. H. Lamborn.*

By this it will be seen that the process is simple and cheap,

though tedious, and that bullion of higher value than $800 per ton had better be cupelled; and if a ready sale can be obtained for litharge at a higher price than lead, a still lower percentage of silver should be also thus treated.

In remote regions, concentration is generally preferable, when the marketable soft lead can be also shipped to advantage.

When arsenic, antimony, sulphur, copper, iron, etc., are alloyed, calcination and "poling" (which have been fully described under the smelting of copper and tin) must be resorted to for the production of a good soft lead, for facilitating crystallization, and for the separation of *the one crystal only* from the other.

EXTRACTION OF SILVER FROM COPPER BY LIQUATION.

It will frequently happen in this country that silver will be found associated with too much copper for effectual milling, and also that lead will be present in no inconsiderable quantity; which will render smelting imperatively necessary for more effectual beneficiation; and in such cases, as neither the methods of Ziervogel or Augustin are available when much lead is present, this of liquation will sometimes become very serviceable.

The principle on which this process is founded is simply that when an argentiferous alloy of about one hundred parts of copper and thirty parts of lead are slowly heated to a degree which is sufficient to melt the lead, but not the copper, the widely disseminated lead elopes with the silver, leaving the spongy disks of copper almost silverless.

If this proportion of lead is not present, sufficient must be added thereto, which is usually done by smelting the ingots in a cupola furnace of about six feet high; a charge of copper being first introduced, and just when it begins to melt, the proper amount of lead. As soon as these are melted to the homogeneous alloy, other similar charges are given to follow, and the metal is tapped and run into iron moulds, to form suitable disks of eighteen inches diameter and three inches thick. These disks being annealed and cleaned by sudden immersion in cold water, which also prevents the lead

from sweating out, are stacked for treatment by liquation, as follows.

The hearth for smelting or partial smelting of the lead from these disks is formed in a very easy manner, by building two long inclining walls on the ground (of about two feet high by one foot wide), twelve inches asunder in the bottom and approaching at the tops (which are covered from end to end with iron plates), to within three inches of each other; the one end, between the walls, is open, and has a kettle for receiving the melted lead, and the other end leads to a chimney, for increasing the heat towards the finish.

The disks of metal are laid about twelve inches asunder, on their edges, across the smooth iron tops of these walls, which form a bottomless valley, and are first surrounded by a vertical fence-wall of thin, suitably shaped, side and end iron plates, or with temporary bricks, and the spaces between are filled with charcoal, to surround and cover the disks.

Wood is next placed within the walls below, which, being kindled, ignites the upper charcoal fire.

The lead will soon exude and fall into the long central underlying channel made for its reception, and will flow back into the kettle at the end; the fire may be gradually increased (by opening the damper of the chimney) towards the end of the operation, for the more effectual extraction of lead, until no more flows, when the lead thus obtained must be cupelled in the manner already described.

The copper disks are then generally further sweated in reverberatory furnaces for more lead (which is first tapped off), and the copper is refined as explained under copper smelting, for its market.

If the cakes of copper were cast or strained by pressure into **V** *shaped moulds, so that they could not lie flat on the hearths, I see no reason why the whole process of sweating and tapping off the lead, as well as the subsequent refining of copper, could not be more easily and effectually performed within a clean and properly sloped reverberatory furnace.*

CHAPTER V.

CHEMICAL REDUCTIONS.

REDUCTION OF ORES, AND SEPARATION OF METALS, BY DRY AND WET CHEMICAL DECOMPOSITIONS, TRANSFORMATIONS, DISSOLUTIONS, AND PRECIPITATIONS.

All the metallic mineral compounds can be decomposed, and their metals reduced, by the wonderful powers of some one or other of the appropriate expensive chemicals; but, for beneficial purposes, we only require a knowledge of such as can be obtained at sufficiently low prices to be available for the profitable extraction of metals.

Fire and water are by far the most important; for the former will so change the constitutional form that the latter may dissolve that which would be otherwise insoluble (as when the insoluble sulphides are heated to volatilize the sulphur of the base sulphide metals, or form the non-volatile and soluble sulphate of silver); or when supplied with a suitable re-agent (as salt), give it a more tractable new form (as the soluble and volatile chlorides of base metals, or the non-volatile and insoluble chloride of silver), which can be readily beneficiated by one of the following processes.

The number of such beneficial elements are few, as all of the best (yet discovered) methods require but fire, sulphur, chlorine, oxygen, and sodium (or other alkaline metals or earths).

Thus, the same elements that were principally at work during the first hot natural stage of the formation of the earth itself—as described in Chapters I and II, Section I, of this book—again become equally efficient in art, when the substance is subjected to the more hasty treatment by fire, to produce the similar initial soluble or insoluble forms for final aqueous beneficiation.

In these fire and humid chemical treatments of metals and minerals, the following more salient facts may be advantageously remembered; for, as all the most valuable processes yet applied are founded thereon, your success will be the more easily attained.

1. When the powdered minerals, or the alloy of the sulphides of copper, iron, and silver, are roasted in a reverberatory furnace, under increasing heat, the copper and iron will be first changed to sulphates, and then to insoluble oxides; whilst the silver will not be oxidized, but will be only changed to, and remain in the condition of, a soluble sulphate, until a greater and sufficient heat volatilizes its sulphuric acid, and leaves the silver in metallic form.

2. If the above carefully treated charge be withdrawn *just before* the silver is thus freed, the *sulphate of silver will be soluble in hot water*, and can be run off; whilst the oxides of copper and iron, being insoluble, will remain in the solid residue.

3. Metallic copper precipitates silver from its sulphate solution.

A knowledge of the above simple properties enabled Ziervogel to apply the method in a most successful manner for the reduction of the somewhat peculiar matte and ores of the Mansfield Company, to which it is said to be better suited than any other method; but, for this reason, it is probable that it may have been too much extolled for general effectiveness on silver ores.

4. By roasting an ore of silver at sufficient temperature, with a suitable quantity of common salt, all the silver contained in the charge will be chloridized.

5. This chloride of silver is insoluble in water and in all acids, but may be readily dissolved in a hot and strong solution of common salt (and in other alkaline liquors).

6. Metallic copper will precipitate the silver from this solution.

Augustin's process was founded on the principles exposed under the fourth, fifth, and sixth headings.

7. When the silver of any argentiferous ore has been chloridized, as under the fourth heading, it may be dissolved in a cold solution of hyposulphite of soda.

8. The base metal chlorides are soluble in hot water.

9. The silver can be precipitated from this solution as a sulphide, by adding sufficient polysulphide of sodium.

Von Patera's method is founded on the principles enumerated under the seventh, eighth, and ninth headings.

The Becchi and Haupt process, as suggested by Dr. Percy, is governed by the solubility of the base metal chlorides in hot water, under the eighth heading.

ZIERVOGEL'S PROCESS—WHEREBY SILVER IS EXTRACTED FROM COPPER MATTE AND CERTAIN ORES—AFTER IT HAS BEEN ROASTED TO A SOLUBLE SULPHATE—BY WARM WATER.

This method, when the ores are suitably composed for efficient extraction, is cheaper than any other yet discovered; but, simple as it appears to be, it is necessary that the workmen shall have great skill and judgment, or, under ineffectual roasting, all will not be sulphatized; whilst, by a too long-continued and too high temperature, it will be reduced to insoluble metallic silver, and be lost. It is necessary that the ores shall contain at least a certain ratio of not less than twenty per cent. of sulphurets, so as to afford the necessary sulphuric acid for the formation of sulphates, and that antimony and arsenic (the former is very plentifully distributed in this country) shall form no considerable portion thereof, or the deleterious insoluble antimoniates and arseniates will be formed.

1. ROASTING.—To manipulate in this process, the argentiferous sulphide of copper matte is taken from the fourth process, or second fusion in copper smelting, granulated and roasted in a reverberatory furnace, until the base metals are oxidized and the silver is sulphatized (at a heat just less than necessary for its reduction).

This is generally accomplished in a furnace having two reverberatory hearths (as the *one* shown at page 498), the one over the other, so that the same current of heated gases may, after passing the lower, return over the upper hearth, in its road to the chimney, by the still further windings of a circuitous flue for catching the fine particles of debris, oxides,

etc. (that would otherwise escape), for future beneficiation. (See, also, page 513.)

The charge may consist of about five hundred pounds of granulated sulphide metal (or five hundred pounds of ore that contains sufficient sulphurets to support the re-actions), which may be first roasted for some five hours or more on the upper hearth, and then transferred to the lower hearth for another five hours' roasting, at the exactly suitable temperature, until *a hot sample, when moistened by a small quantity of water on a saucer*, will, when filtered, give a *milky solution, or curdy precipitate of chloride of silver, when a drop of salt water is added.*

Although this filtered solution may appear slightly blue, it should not be green, or sulphate of copper will still remain unoxidized in the charge, which is indirect proof that the silver has not been all sulphatized.

From eight to ten hours is generally required for this roasting.

2. Dissolving or "Leeching" the Sulphate of Silver from the Roasted Charge, by Hot Water, and Precipitating the Silver.—For this purpose, four long and receding steps or terraces are constructed to receive as many rows of tubs, the top row being of sufficient capacity for holding about 1000 pounds of roasted matte or ore, and the necessary water; the underlying rows may, however, be smaller, as half this size. (See Cut 62, in Augustin's process.)

The upper or first row, and the third and fourth rows, of tubs, must have hollow and perforated internal false bottoms, which may be supported on bearers, over and upon which linen filters must be stretched on hoops (in the manner of a drum's head or tambòrine), which may jam down in the tapering tub to a close external joint against the tub; whilst the central linen part shall lie on a layer of straw, which intervenes between it and the perforated false bottom. The second row of tubs are merely receivers and settlers of debris from the dissolved sulphate. The third and fourth rows of tubs must be made to filter like those of the first. Under these four rows are placed, on or in the ground, a reservoir to catch the still hot water, from where it is raised by the pressure

of steam, into the warming apparatus, to increase its temperature for repeated passage through the ore, until all the silver has been extracted; which may be known by testing the filtered liquid with salt water, in a small test tube.

The roasted matte or ore, as discharged from the furnaces —*which, for greater convenience, should lie just above these tubs*— is placed in charges of about four hundred pounds, in each tub of the top row, and water, heated to about 160°, is supplied through as many appropriate regulating cocks, as it filters and passes away by other taps into the second row of receiving and settling tubs.

The liquid sulphates next pass by another cock near the bottom (probably this would be better placed higher, as near to, or at the top), into the third row of tubs, which must have ten or fifteen pounds of copper shot, and some three hundred pounds of blistered bar copper, to precipitate the silver from the solution.

This partially or wholly desilverized solution must now be made to filter and pass into the fourth row of tubs, over another layer of copper, so as to precipitate any silver that may have escaped from the third row of tubs, and thence through the underlying filter and tap into the last reservoir, from whence the liquor is elevated and warmed, for repetition of the process.

As it will be generally found advantageous to insure the acidity of the liquor by the addition of a little sulphuric acid, the warming vessels should be lined with lead, and the taps be made of solid lead, or of wood.

Three and a half hours are sufficient for extracting the silver, when the cupriferous residues are taken from the tubs to the copper smelting department, where (if the silver has been properly extracted, as proven by especial assays) the copper oxide is smelted and refined.

Nearly all of the silver will be deposited in the third row of tubs, which, with that in the fourth row, may be cleared away as often as necessary, and sufficiently refined by fusion in a suitable furnace, by one of the methods described under "Smelting and Refining."

The silver obtained by this treatment is of some $\frac{980}{1000}$ fine, the base metal being principally copper.

AUGUSTIN'S PROCESS FOR THE EXTRACTION OF SILVER FROM COPPER MATTE AND ITS ORES.

Next to that of Ziervogel, this is the cheapest means for the extraction of silver from the sulphide matte from copper smelting; and looking at the greater certainty of the silver being chloridized than sulphatized, and its more general adaptability to all ores which can be roasted without clogging or agglutination, and ease of manipulation, it appears to be much more suitable for the very diversified and intimately mixed ores of this country.

The difference of cost is but insignificant, if the former process should fail to extract, and the latter succeed; which, of course, it will do, whenever silver can be effectually chloridized by fire. This process was invented before that of Ziervogel for separating silver from the peculiarly regular copper matte, and ores at Mansfield. The method of Ziervogel answers best for that purpose, and, as stated, may have had too much importance attached to it for advantages in treating the ever-varying minerals of the world, outside of that particular district.

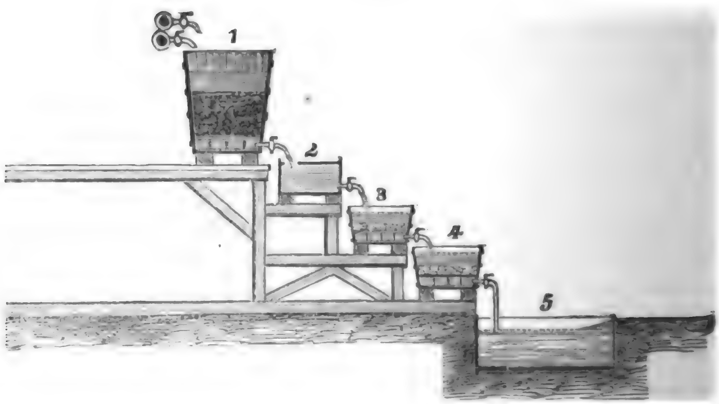
Augustin applied double fire treatments; in the first, the finely pulverized matte was simply desulphurized in a plain reverberatory furnace (like Cut 45, page 498), in charges of four hundred and fifty pounds, just as described at pages 500, 504, 505, 506, 507, and 508; whilst the second was for chloridation with salt, after the resulting charge had been again pulverized between millstones, and bolted like flour to an impalpable powder.

For silver ores, it will be all-sufficient to roast and chloridize during one heating, as described from pages 509 to 513; and the hill-side furnace shown by Cut 47, at page 504, will be found very serviceable, which may be made to stir in a self-acting manner, by machine rakes. The slope of each hearth may then be made to suit your particular ore, as regards the time required for its passage.

This chloridized ore must be withdrawn and charged into the upper series of dissolving (lixiviating or leaching) and filtering tubs, which may be four feet high, three feet in diameter at the top, and two feet six inches at the bottom.

About 1000 pounds may be charged in each, to lie loosely over the hollow bottom, upon the linen filter which has been described at page 603. The chlorides of silver and copper are now dissolved in a hot and strong solution of salt and water, which, filtering through the linen, runs through the top, to fall and settle in the underlying second row of vessels, thence into the third row, which has a similar filter and bottom, and upon which about six inches deep of cement or granulated copper is placed, which precipitates the silver; the partially desilverized solution now passes through the filter, into the next or fourth row of tubs, which also contain copper, so as to precipitate any silver that may have escaped from the third row, or first series of precipitating tubs. The completely desilverized solution now passes into the last, or

Cut 62.



fifth row of tubs, wherein metallic iron is placed to precipitate the copper, when the solution is raised by the pressure of steam, to be warmed for repetition of the process on other charges. The time required for roasting is about eight hours, and for chloridizing thirty minutes. The solution should be heated to 160°, and contain about twenty per cent. of salt. The depths of the layers of copper and iron should not be less than four inches.

The cement silver may be taken from the third and fourth rows of tubs, when necessary to do so, freed from the mechanically adhering copper by hydro-chloric acid, then washed by water, pressed into balls, dried, and refined into marketable ingots.

VON PATERA'S METHOD FOR THE EXTRACTION OF SILVER.

Dr. Lamborn describes this process as follows.

"During a recent visit to the mines and furnaces of Joachimsthal, I was given every facility for studying this system, which was put in operation in 1858, and up to this date has produced about 4000 pounds of silver.

"The ores of Joachimsthal are remarkable for the numerous mineral species composing them. More than one hundred varieties have been described as occurring in the veins from which the precious metal is procured. Among these may be mentioned the various compounds of copper, lead, bismuth, iron, nickel, and cobalt, with sulphur, oxygen, arsenic, and antimony. The remarkable richness of these ores has heretofore been adverted to. When the entire quantity delivered at the furnace is reckoned, the silver is found to compose two to three per cent., and many hundred weights are worked from which five to eight, and even as much as fourteen per cent. are extracted. The fuel used at the furnace is brown and stone-coal, wood, and charcoal. The first is moderately cheap, the second dear, and the third and fourth are becoming less abundant each year. Labor, on the other hand, is abundant, good workmen receiving only 1*s.* to 1*s.* 4*d.* per day.

"The ore is in part prepared by hand-sorting, and part by concentration upon the *percussion table.* It is delivered to the furnace in a powdered condition, and stored in appropriate magazines until required.

"The first operation to which it is subjected is—

"ROASTING.—This process is performed in a reverberatory furnace, which presents several peculiarities that recommend it to the attention of the metallurgist. The usual long, narrow hearth and fire-bridge, and short fire-place, is here replaced by a hearth nine feet nine inches across, and six feet in the direction taken by the flames on their way from the fuel to the chimney. The fire-place, instead of being two feet across, as is the case with many English furnaces, is here but six inches, and the grate upon which the fuel is consumed, instead of passing along about one-third of the side of the furnace, as is often the case, is here four-fifths as long

as the hearth. The advantages secured by this arrangement are obvious to one observing the action of the furnace. The broad and short hearth makes possible an equal and high heat throughout the whole furnace, and the long fire-place allows no portion of the charge to remain in remote corners, beyond the reach of the intense fire; while the narrow fire-bridge absorbs less heat, and allows the flames to have a more direct action upon the contents of the hearth than where a broad mass of bricks intervenes between the consuming fuel and the mineral that is being treated.

"A further important innovation distinguishes this furnace from others of the same class. The fire-bridge is a tube of iron covered with clay, and having eight to ten small openings in the side toward the hearth. A boiler attached to the furnace, but heated by a separate fire, produces steam of the pressure of about four pounds to the square inch, which can, at the will of the operator, be conducted into this tubular fire-bridge, and allowed to stream out from the openings upon the roasting charge.

"The powdered ore, as it comes from the mine, is placed in the furnace in charges of 4 cwt. It is subjected to a slight fire at first, which is gradually increased, but not to a point high enough to induce clotting. Vapor is not admitted at first; but when the charge has arrived at a red heat, the pipe connecting with the boiler is opened, and as much vapor allowed to pass over the heated ore as is possible without decreasing the temperature below the point necessary for the proper chemical changes to go forward. In four hours the process is complete, and the ore is drawn, permitted to cool, and carried to a mill, where it is ground to fine powder, being at the same time mixed with some salt. It is then brought to the roasting furnace, to undergo what is known as the *good roasting*. Three hundred weight of the ore are here treated at once, being first intimately mixed with six to twelve per cent. of common salt, and, at the same time, with two to three per cent. of iron vitriol. This mixture is spread upon the hearth; in about an hour after being brought under the influence of the fire, a red heat is reached; the vapor is then let on as before, and stirring commences. The fire is gradually made stronger, and in from six to sixteen hours—

depending upon the value of the ore—the process is concluded.

"The object of adding salt is to form with the silver a chloride. The vitriol furnishes a means of decomposing the salt, when not enough sulphides are otherwise present; and steam makes the combination of the chlorine and silver more certain, and by condensing the vapors that pass into the chimney and condensing chambers before they can reach the open air, enables the catching of nearly all the silver. Were it not for this contrivance, ten per cent. of the silver would be lost, which would evidently make the treatment of rich ores by this means impracticable.

"The roasted ore, still in a finely powdered condition, is transported to the apartment devoted to lixiviation, where the various apparatuses for solution and precipitation are arranged, as is shown in the accompanying cut, which gives a vertical section from one end of the building to the other, and which will be understood by reference to the following description.*

"FIRST LIXIVIATION.—The powdered ore now contains the silver as a chloride, and hence insoluble in water; while some of the nickel, cobalt, zinc, copper, etc., are present as sulphates and chlorides, and soluble in that fluid. Charges of 4 cwt. are thrown in the row of tubs represented by A, which are made of pine wood, well hooped with iron, and furnished with a filter, *a*, at the bottom. Water at as high a heat as possible is thrown upon this ore for about six hours, and thus all the soluble salts are taken into solution, and carried through the filter, *a*, into the trough, *b*, to appropriate vessels, where they are precipitated with lime-water, and if rich enough in silver, are collected and sent to be fused in a cupola furnace.

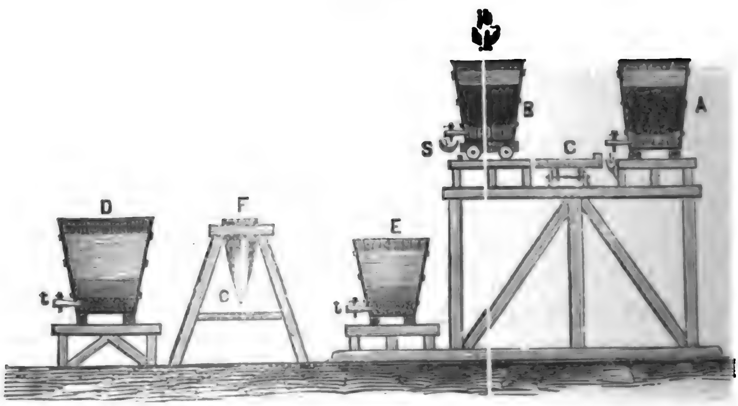
"The fluid, falling into *b*, is occasionally tested with the sulphide of sodium; and when no precipitaie appears, the first lixiviation is deemed ended, and cold water is thrown in

* The employment of solutions of hyposulphite of soda (for the extraction of silver from its ores), and the polysulphide (for its precipitation), were first suggested by Dr. Percy, published in 1848, and then translated into the Austrian language; which should have been stated in the fourth line of page 602, for the Von Patera process, instead of for that of Becchi and Haupt.

to diminish the temperature of the ore, which must not be submitted to the next treatment until quite cold.

"SECOND LIXIVIATION.—The powdered ore, thus disencumbered of the several salts, soluble in pure water, is now thrown into the tubs, represented by B, which are also constructed of pine, and resemble in their interior arrangement the vessel used in Augustin's process. Of these vessels, seven are employed in the establishment at Joachimsthal. They are placed on a level with the vessels, A, and between the two rows passes a small railway, upon which runs the car, C. The vessels, B, are placed upon a small wagon, W, that can be run from the position shown in the cut to the car. C, and then carried backward and forward, and brought into

Cut 63.



close proximity with any of the tubs in the row, A. The vessel, B, having received 2 cwt. of ore from one of the larger tubs, is set in its place, and treated with the liquor intended to dissolve out the silver. This consists of a cold solution in water of the hyposulphite of soda. This fluid is brought from an appropriate reservoir by the trough, *h*, and allowed to filter slowly through the mass. It takes up the chloride of silver in the form of a double salt, and conveys it in solution through the filter, *l*, and thence into the trough, *s*, whence it flows into the precipitating tubs, D and E. The rapidity with which the fluid will flow through the powdered ore depends upon its fineness, and the length of time required

for extracting all the soluble silver in the tub depends upon this mechanical circumstance, and upon the quantity of silver in the ore. The richest mineral brought to the extraction, which contains about fourteen per cent., requires forty-eight hours: that containing one per cent. requires twelve hours. The ores containing but six or seven per cent. require but one lixiviation, which brings the remainder down to about one-sixth of a per cent.; but the ores of higher value must be submitted to two lixiviations, with an intermediary roasting with vitriol and salt, before they can be reduced so far. The remainders are dried and given over to fusion in a cupola furnace. The charge in each tub, B, is known to be ready for removal when the liquor falling from it no longer contains silver, which fact is known by a trial with a solution of sulphide of sodium, a re-agent that will produce a dark color when only a trace of silver is present.

"PRECIPITATION OF THE SILVER.—The argentiferous liquor falling from the vessels, B, is conducted into the tubs represented by E, of which there are six, each holding about forty gallons, and into those represented by D, of which there are four, each holding about eighty gallons. When one tub is nearly full, the trough carrying the liquor is changed to another, and the precipitation of the silver may commence.

"The plan here adopted is an exact imitation of a delicate laboratory process; and it is worthy of remark that the common workmen have attained such a facility in performing it, that they never fail in producing the desired result. The precipitant is the *polysulphide of sodium*, formed by calcining soda with sulphur, and afterwards boiling the product, when dissolved in water, with sulphur in a state of fine division. It is conveyed to the tubs in large stone jars, and poured into the argentiferous liquor, until all the silver is supposed to be thrown down, stirring being vigorously carried on at the same time. The workman now dips a little of the clear liquor out in a glass tube, and adds polysulphide of sodium. If a dark color is produced, it is a proof that silver is still in solution, and more precipitant is added from the stone jugs; if, on the contrary, no sulphide falls in the test tube, it is a question whether too much sulphide of sodium has not bee

added to the tub; and to prove this, some of the fresh silver-holding liquor is added to an assay taken from the tub under treatment. If, in this case, a precipitate is formed (of sulphide of silver), the same fresh argentiferous liquor is added carefully to the tub, until no re-action of sulphide of sodium is produced. When this point is reached, all doubt that the whole of the silver has been precipitated, and that no excess of the precipitant remains, is removed by the application of still more delicate re-agents: acetate of lead, to detect the excess of sulphide; and the solution of some chloride, to prove the presence or absence of silver. This exact condition of neutrality is essential to the success of the process, since the fluid from which the silver is thrown down is again given to the lixiviation, and the presence of sulphide of sodium in the tubs used for solution (B) would lead to the formation of an insoluble sulphide of silver, and hence would prevent the method succeeding. The process of precipitation, complicated as it may seem, requires the labor of two workmen only fifteen minutes for each tub, even when the largest vessels are treated.

"The flocky precipitate is now allowed six hours to settle to the bottom, when the liquor above is drawn off by means of a syphon, and the dark sulphide of silver, which exists as a slime, is drawn off through the spiles, *t t*, which enter at the lower part of the tub.

"The liquor from the syphons is carried to a reservoir beneath the floor of the apartment, and thence pumped up to the level of the trough, *h*, to be again used in the process of dissolving. It is a curious circumstance in the history of this method, that no hyposulphite of soda has been added since the commencement of the operation, when fourteen pounds were dissolved as a beginning. The sulphide of sodium, when exposed to the air, forms a small quantity of the hyposulphite of soda, so that this essential salt enters the circuit when the silver is precipitated, and thus the solvent, instead of becoming weaker, is continually concentrating, and must frequently be diluted by the addition of fresh water.

"TREATMENT OF THE SULPHIDE OF SILVER.—The precipitated mass from the tubs, D and E, is deposited in three-

cornered bags of hempen stuff, and hung in the wooden frame, F, to drain. In about half an hour, the dark mass, which, beside sulphide of silver, consists chiefly of sulphate of soda, is placed, while still in the bags, beneath a screw press, and the fluid that remains in it is forced out as completely as possible. It is then dried in a warm room, placed again in the filtering bags, and warm water thrown over it, to wash out the sulphate of soda. The sulphide of silver, thus freed of its soluble salts, is now dried a second time, and heated in a muffle, to which air has access. The sulphur burns out with the characteristic blue flame, and in about three hours the entire mass is almost entirely reduced to the condition of metallic silver, which, in some instances, assumes the thread or wire-like condition that is frequently seen in specimens of native silver.

"The last process, which consists of a fusion, is now accomplished. The metal is placed in a graphite crucible, of Passau or English make, to the amount of three hundred pounds, and fused. The sulphur that still remains is removed by placing metallic iron in the fused metal, and thus inducing the formation of a ferruginous regulus, which rises to the surface and is skimmed off. The surface of the metal is then cleared by adding a mixture of bone ash and wood ashes, and the silver dipped out and poured into moulds. The silver varies in purity between .980 and .985, and is at once sent to the Imperial mint at Vienna.

"The workmen who have charge of this apparently complicated process were formerly engaged in the smelting department, and have no knowledge of theoretical chemistry; yet the whole affair is carried forward with the utmost regularity, and but occasional attention is required from the superior officers. The cost of extracting a pound of metal from the ore amounts to about 9*s.* 9*d.*, which is about 6*s.* less than the cost of separating the same amount of metal by the old process of smelting."

PROCESS OF BECCHI AND HAUPT, AS USED IN TUSCANY.

The sulphuret ores are broken to the size of hen's eggs, and about two hundred tons are roasted in heaps, with layers of wood, for some twelve or fourteen days.

This volatilizes sufficient sulphur, and renders the stone more friable, for pulverizing between mill-stones.

The finely pulverized ore is now subjected to a chloridizing roasting, with sufficient salt to change all the copper to a chloride, which requires some fifteen minutes (after the proper temperature has been attained), under continual stirring.

The roasted charge is now placed in vats, and the chloride of copper is dissolved out with hot water, filtered into, or allowed time to settle and run into, still another vessel, and precipitated with metallic iron, or with caustic lime-water; it is then smelted in a low cupola furnace, and refined in the manner already described under "Copper Smelting."

PROCESSES SUGGESTED FROM CONSIDERATION OF THE PRINCIPLES WHICH GOVERN THE FOREGOING METHODS, FOR THE BETTER EXTRACTION AND SEPARATION OF SILVER AND COPPER FROM EACH OTHER, AND FROM OTHER BASE MINERALS.

The extraction and separation of silver and copper from each other, and from the other base minerals, may be frequently accomplished as follows.

FIRST PROCESS.—Roast and chloridize the silver, with the copper and other base metals. Dissolve these copper and base metal chlorides in hot water, filter and precipitate the copper by iron, or with caustic lime. Treat the solid residue in revolving barrels, with iron and mercury, as directed at page 542; or in copper-bottomed kettles, with salt, as explained at page 538.

SECOND PROCESS.—Chloridize and precipitate the copper, as in the first process; then dissolve the silver in a hot solution of salt, filter and precipitate the silver with *copper stirrers*, in copper-bottomed pans, either with or without mercury.

THIRD PROCESS.—Roast the pulverized ore until the sulphate of silver is formed, which dissolve out with hot water, and precipitate with copper, as directed by Ziervogel. Then, instead of smelting, add twenty per cent. of sulphuret of copper, that contains no silver; chloridize the copper by a second roasting, dissolve in hot water, filter, and precipitate the copper with iron or lime.

Fourth Process.—Chloridize all in furnace, with salt; dissolve and pass away the soluble base chlorides in hot water, and beneficiate the insoluble chloride of silver in copper-bottomed kettles, either with or without mercury, as exlpained at page 538.

In the interior of this country, salt is frequently found in great abundance, and where moderate quantities of wood can also be obtained, one or the other of these processes or modifications may be used to most effective advantage for reduction of silver ores.

In conclusion, I must say to those practicals who have had sufficient perseverance to read thus far, that this book has been extended to a much greater length than was at first intended; but being printed closely, on very thin paper, it is still of companionable size. I trust that nothing of importance has been omitted; nor anything written which will not be of interest to all, and valuable to many.

To critical readers I may say, that although the scientist will disagree with some of my notions, and the better educated professional scribe will see many ill-expressed, bungling passages, that practical men will appreciate the endeavors of one whose life has been too peculiarly operative for very correct expression or refined language. The work has been written in eight months, amidst continual interruptions of business, and immediately printed from first manuscript, to meet the requirements of the present moment's *furor* for the exploration and mining of this country.

To capitalists I commend it as being executed under the influence of a sincere and earnest desire for the general beneficiation of the (should be) immense interest of Mining, by affording all of the necessary facilities for genuine practicals, in legitimate mining; by exposing and condemning the damaging results that have been produced by illegitimate pretenders, white-handed theorists, and the wily intents, foul purposes, and highly detrimental results of market miners.

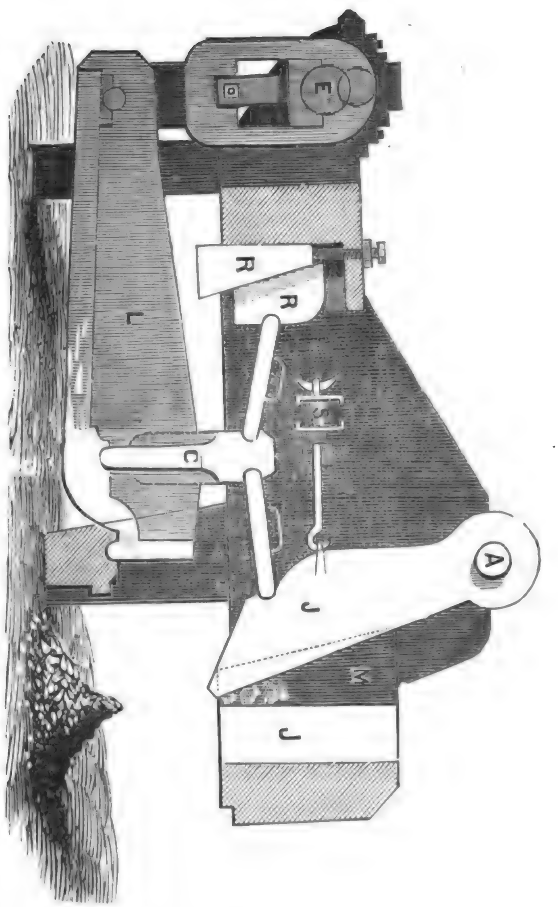
If this labor of exposition of these various departments, and follies, of Mining, will produce better success in the future, I shall have literally and substantially attained more than one desirable end.

AMERICAN MACHINES FOR MINING AND REDUCTION PURPOSES.

The following interesting cuts are more particularly inserted for British readers, so as to give them a better idea of the peculiar American appliances for reduction, etc.

Cut 64.

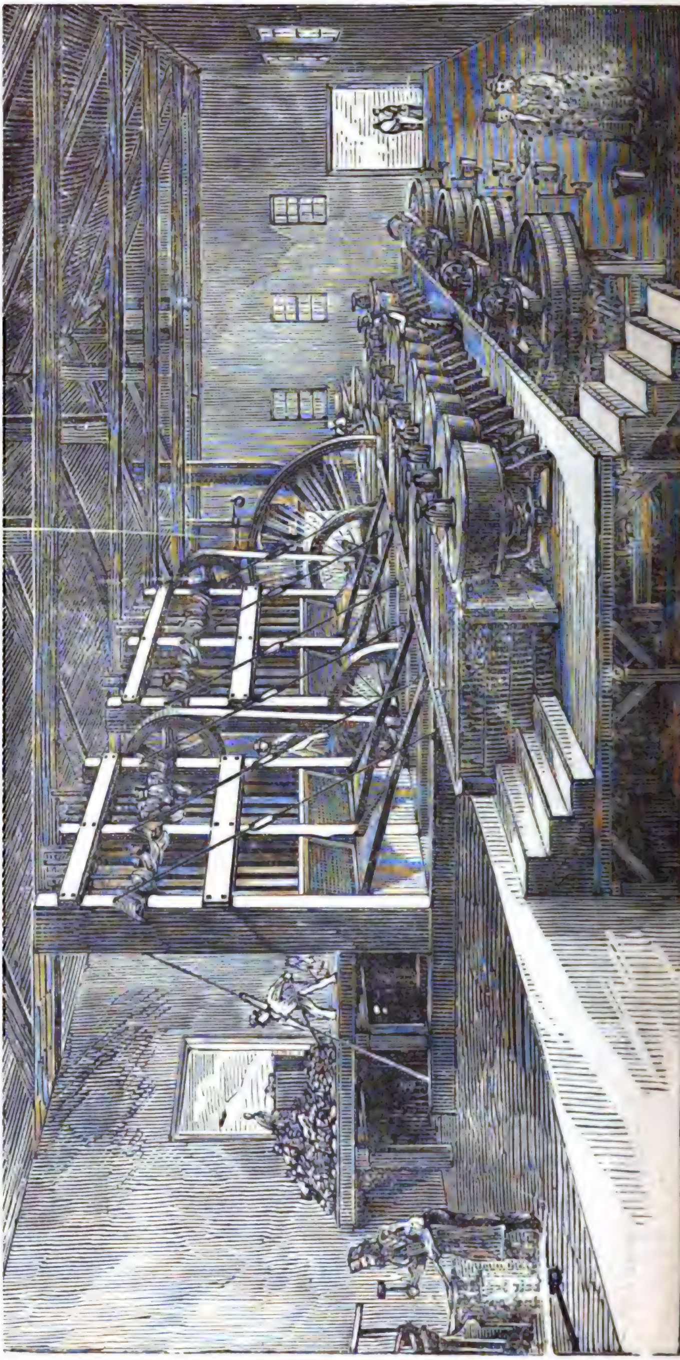
Cut 64 serves to expose the well arranged general principles of Mr. E. W. Blake's portable rock-breaker, which is also made sufficiently large for the partial crushing of rock to suitable sizes for milling and smelting.



The mechanical eye will observe that its adjustment for obtaining any desired size, is as simple as effective; that whilst its crushing strength is enormous, friction has been reduced to a minimum; and that the power is applied in such a manner that fracture is almost impossible.

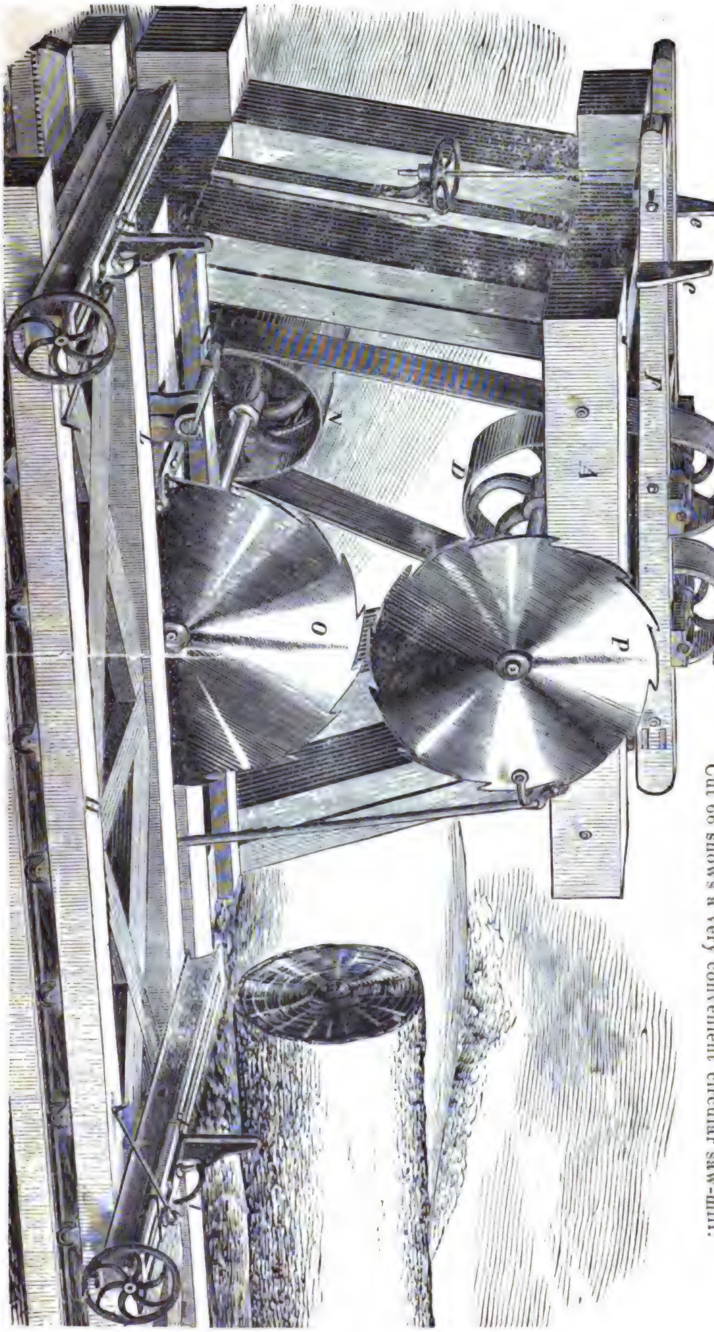
This cut shows a section through its middle, and a view of the further side.

The eccentric crank, E, is driven by its shaft (which has two fly-wheels, one on each side, but not shown), to work the underlying lever, L, which raises the column, C, until its lateral white head bars form a T, and their lengthening forces the nearer jaw, J, against the further jaw, J, which crushes the intervening rock, to fall in smaller pieces, until it passes through the bottom to the floor, as shown. The jaw is withdrawn by the spring, S, for repetition of motion, and the rock descends accordingly down the mouth, A, to fall through the throatway. R R are wedges for regulating the size of the rock thus crushed, as moved up or down by the appropriate screw.



Cut 65.
California Battery, or Stamps, with Pans and Settlers.

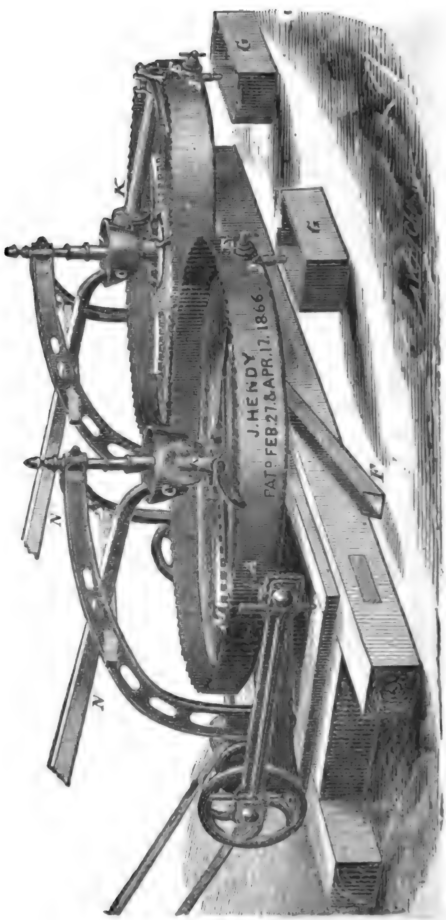
Cut 66.



Cut 66 shows a very convenient circular saw-mill.

Hendy's Improved Patented Self-Discharging Sulphurets' Concentrator.

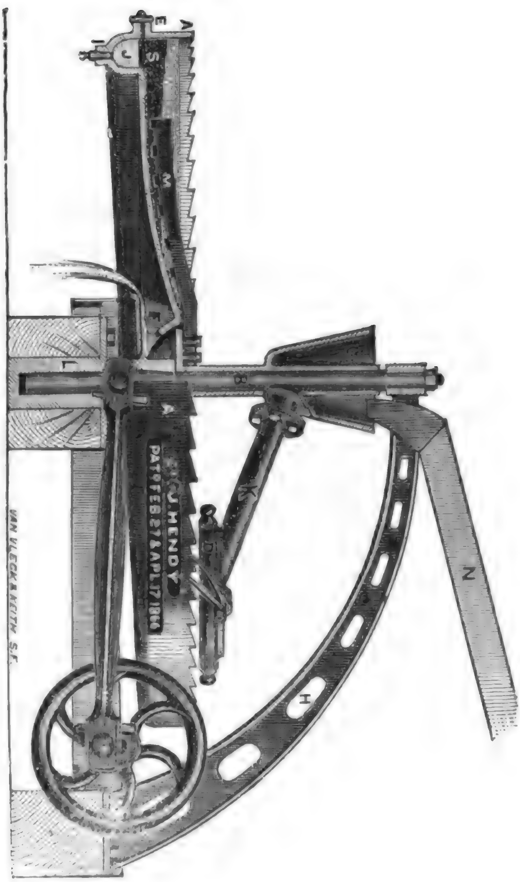
Cut 67.



See explanation of the section (Cut 68), on the opposite page.

Cut 68.

Sectional View of Hendy's Patent Concen



DIRECTIONS FOR OPERATING HENDY'S CONCENTRATORS.—The sulphurets are drawn off while the Concentrator is in motion, in the following manner:

First. In setting up, set the pan, A, level by the inner rim, near its centre.

Second. While in operation, keep the pan, A, about half-full of sulphurets.

Third. Open the gate, E, sufficiently to discharge the sulphurets as they accumulate over the amount above mentioned.

Fourth. The crank shaft to make 200 to 220 revolutions per minute.

Description of the Concentrator.

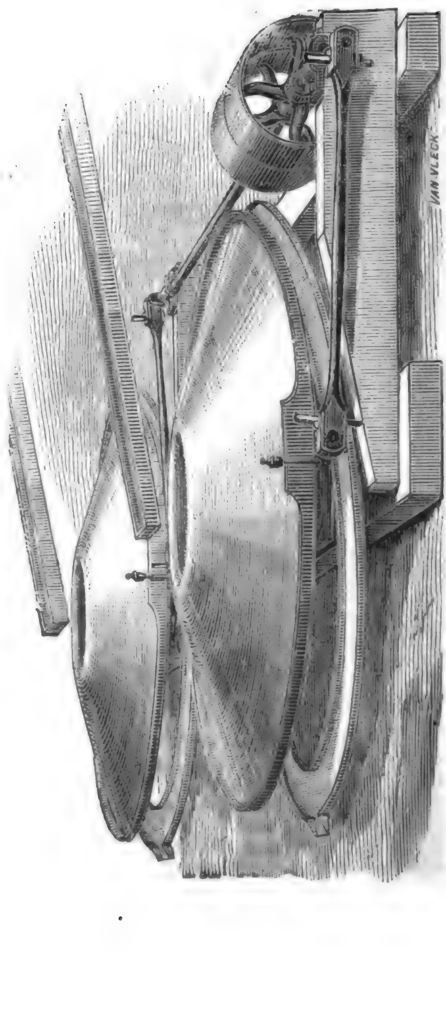
Cut 68 is a sectional view. H is the support for the upper end of the shaft, marked B; L is the step: C, the hopper, into which the tailings are thrown; these flow down the arm, K, and are then distributed at the distributor, marked D. The tailings enter the pan, A, at its periphery, and the debris discharges near its centre, and passes off in the spout, F. The sulphurets discharge at the gate, E; amalgam and quicksilver at plug I. J is the ascending channel, for forcing the sulphurets, amalgam, and quicksilver to their respective points of discharge; S is the sulphurets; M, the stirrers, with rake-like teeth. The rotating of the stirrers prevents the sand from packing near the center of the pan, where the motion is diminishing. The pan, A, shows a curvelinear bottom, which gives a more precipitous descent near its centre, for the purpose of forcing the sulphurets towards the periphery. It will be noticed that the centrifugal force and motion diminishe towards the center of the pan, for which reason the inclination is increased for the purpose above mentioned.

Upon the under side of the distributor are small openings or perforations, through which the pulp is dropped from the feeder into the pan.

The stirrers, marked M, and the distributor, D, are made to sweep slowly around by means of the ratchet teeth upon the upper edge of the pan, in which two pawls are seen to work. This motion is obtained from the vibrating action of the pan. These pans can be so connected, as in Cut 67, that two can be driven by one shaft pulley.

Cut 69.

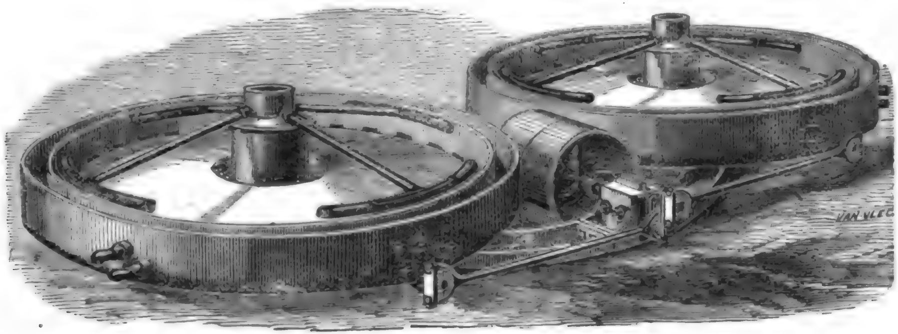
Hungerford's Patented Concentrator.



This concentrating pan is shaken by rods, in similar manner to Hendy's; but the pulverized ore is not smoothed or raked by ribbons or brooms, as caused to travel by the rack on the notched periphery. Its general shape is as shown.

Hungerford's Patented Improved Concentrator.

Cut 70.

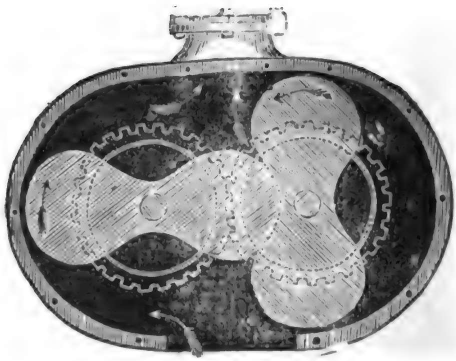


This is an improvement over the original concentrator, as the T pipes serve to disperse the pulp more equally over the pan's bottom.

A still later appliance, for distribution (not shown), has been found very beneficial, as realized by bent tubes (like a barker's mill), which, by supplying the water and debris, in the one direction only, upon a perforated annular trough, causes a continuous circular motion of water and deposition of the pulp, for concentration. (E L. Montgomery, of San Francisco, is the proprietor of these concentrators.)

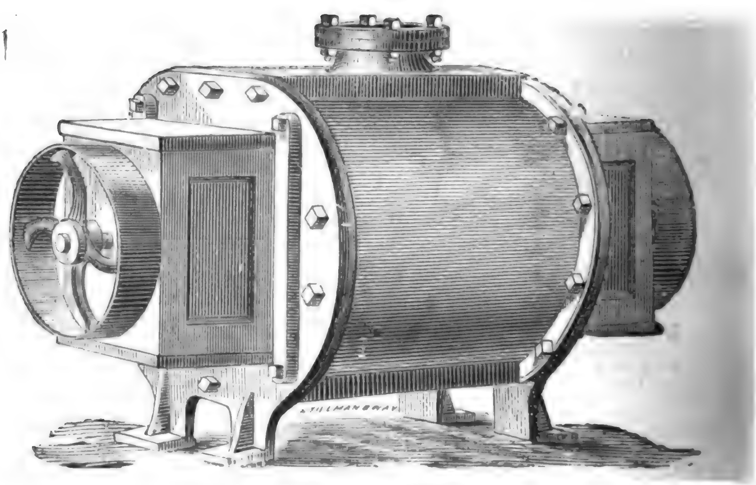
Root's Blowing Machine, for Blast Furnace or Ventilation.

Cut 71.

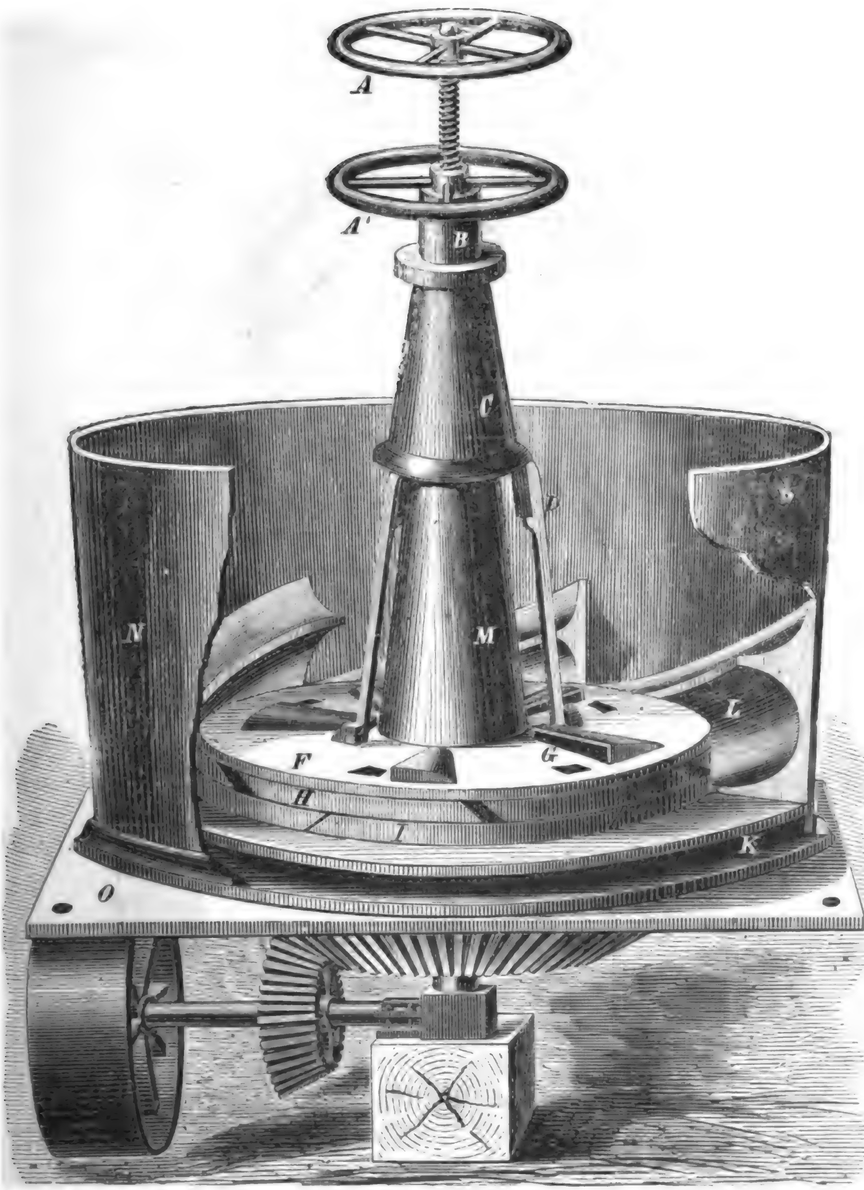


Cut 71 is a longitudinal section, showing the interior of this blower, which explains itself.

Cut 72.

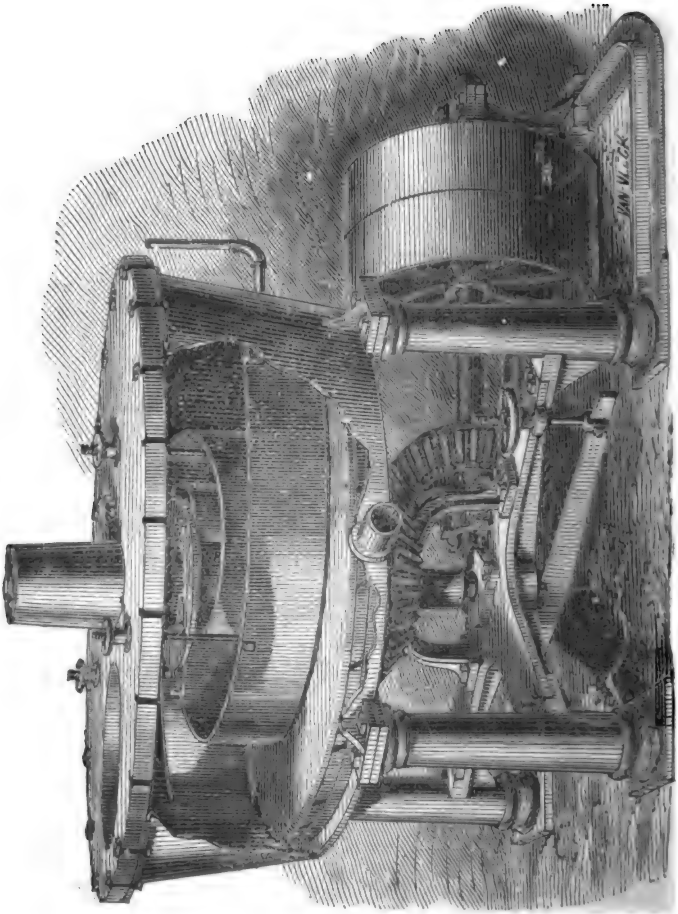


Cut 72 is an angled view of its exterior, which shows how it is fixed and driven by double belt pullies.



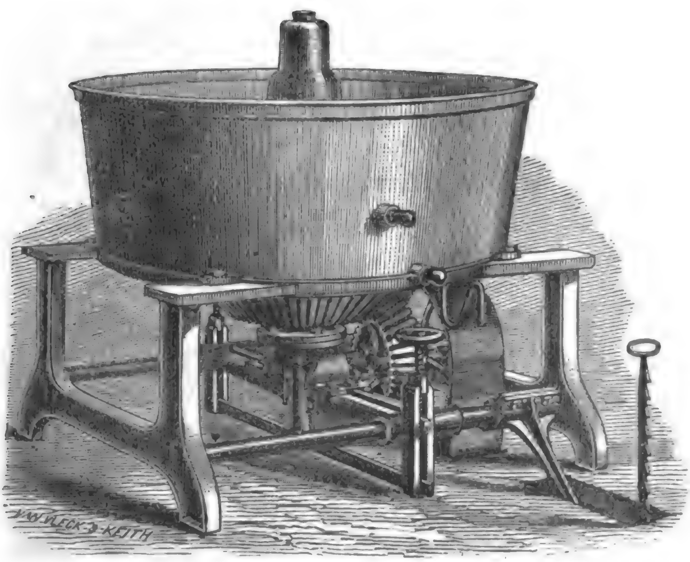
Stevenson's Patented, Mould Board, Amalgamating Pan.

Cut 74.



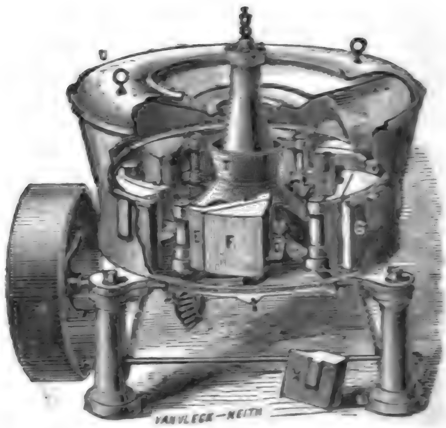
Varney's Patented Amalgamating Pan.

Cut 75.



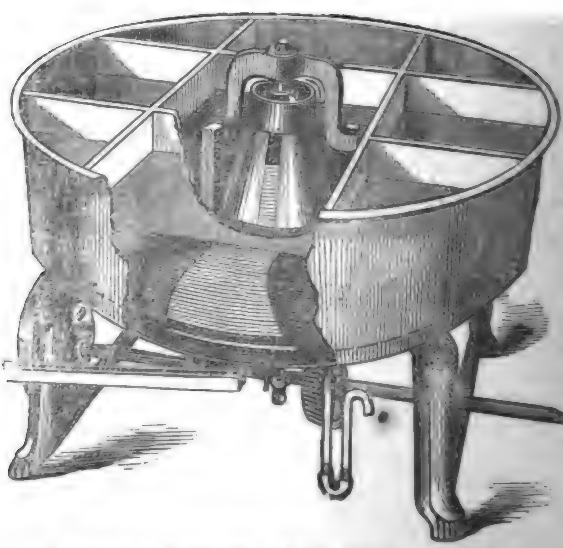
Wheeler's Amalgamating Pan.

Cut 76.



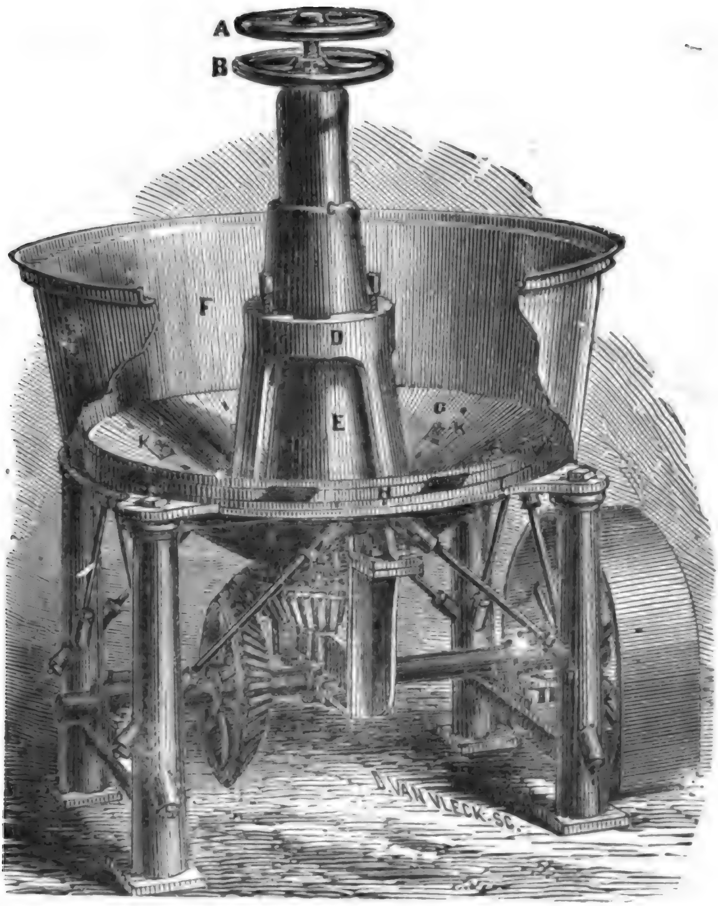
Hinkle's Amalgamating Pan.

Cut 77.



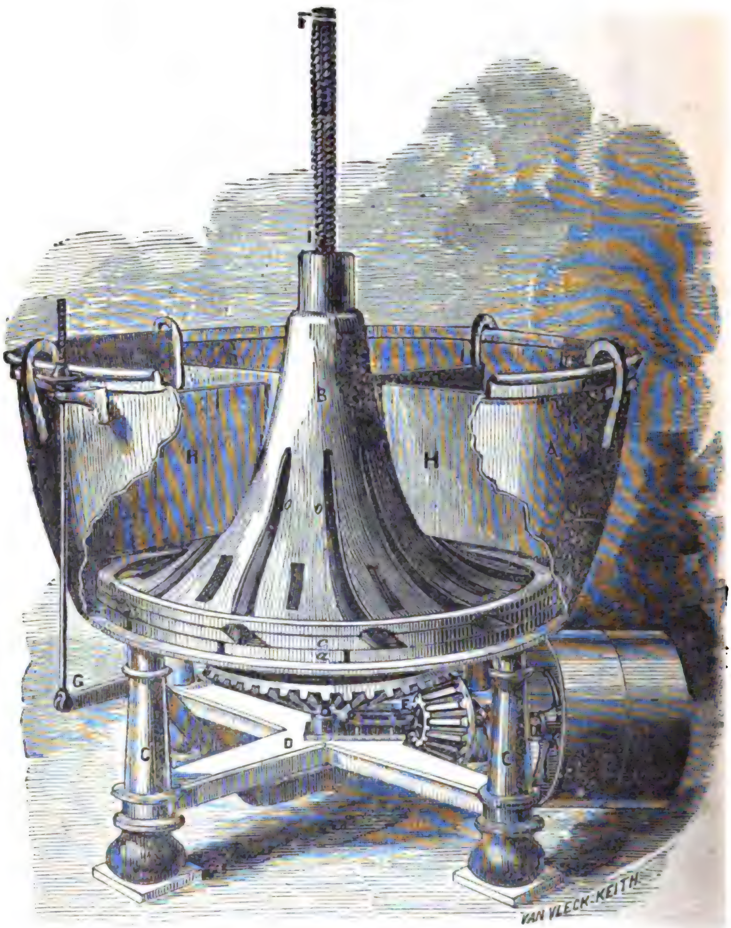
Knox's Patented Amalgamating Pan.

Cut 78.



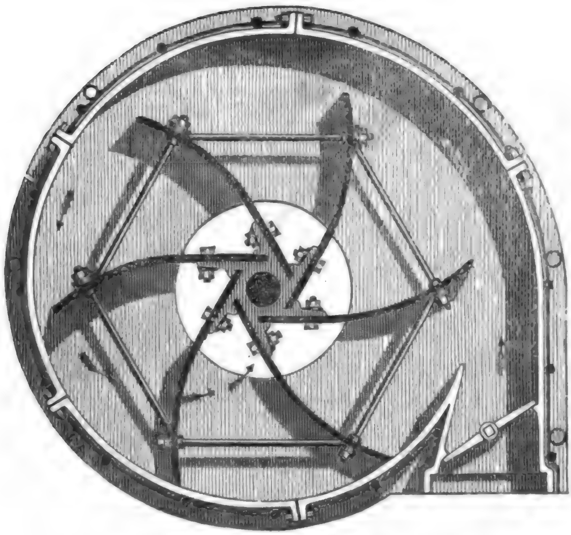
Hepburn and Peterson's Amalgamating Pan.

Cut 79.



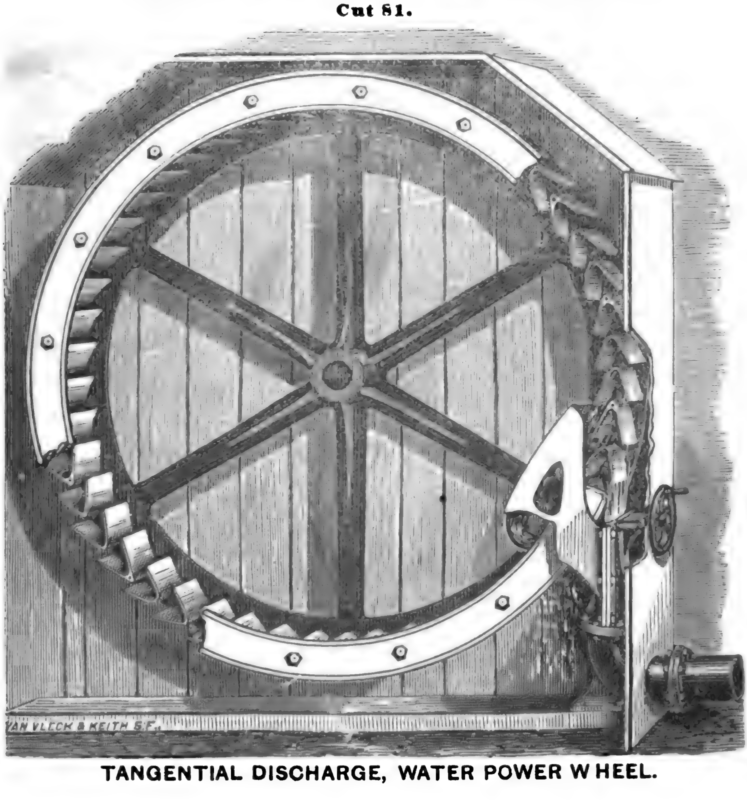
THE EXCELSIOR AMALGAMATING PAN.

Cut 80.



CENTRAL DISCHARGE WATER POWER WHEEL.

Cut 81.



TANGENTIAL DISCHARGE, WATER POWER WHEEL.

INDEX.

APPENDIX.

A NEW METHOD—FOR THE AMATEUR'S MORE DIRECT EXAMINATION OF MINERALS, FOR THEIR USEFUL AND PROFITABLE ELEMENTS—BY BLOWPIPE.

The following safe, simple, and direct tests, have been devised and arranged for ordinary men, so that they may know what useful elements are present in minerals, without having to ponder over and puzzle themselves with all the irregular and complicated random rounds of re-actions, in qualitative analysis; which can only be fully comprehended after years of arduous practice, and deep study.

Before entering on the following course of tests, it will be necessary that the practitioner should be acquainted with, and be able to effect the various manipulations described in Capter IV, of Section III; as, how to produce the oxidizing and reducing flames, page 140; the discrimination on charcoal, pages 142 and 143; smelting with fluxes on charcoal, pages 146 and 147; examination in forceps, page 148; discrimination by fluxes in the platinum wire loop, pages 148, 149, and 150; the uses of open, and close ended, glass tubes, over spirit lamp, at pages 151, and 152; and examination by smelting and water washing, for small quantities of the metals, at pages 152, and 153.

The practically useful and profitable minerals worked by miners, are composed of the following elements.

Antimony, arsenic, bismuth, chlorine, chromium, cobalt, copper, iron, lead, manganese, mercury, nickel, sulphur, tellurium, tin and zinc; with the magnesian, aluminous, quartzose, and lime rocks.

Before commencing your tests, write these names on a slate, or on paper, and then proceed as follows.

Thoroughly fuse some of the finely pulverized ore with carbonate of soda, within the small terminal eye or loop of platinum wire, in the oxidizing flame; and notice the color of the glass.

If the glass is pale yellow? Chromic acid is present, from some chromate ore.
If the glass is of a bluish green? It has been produced by manganese.
If of a copper red? From copper reduced by this flux.
If of a lead colored enamel? From reduced lead.

If not thus colored, erase chromium and manganese from your list, and test for the remainder.

Fuse in similar manner with borax.

If the glass is blue! The mineral is cobalt.
If light bottle green? Iron.
If amethyst? Manganese. (But this would not be present if the carbonate of soda failed to show it.)
If of a reddish brown? Nickel.

If neither color? Expunge cobalt, iron, and nickel from the list.

Place a small piece of the mineral, of about the size of a grain of wheat, upon un-fluxed willow or pine charcoal, and subject it to the oxidizing flame of the blow-pipe, until an intense heat is produced, which continue for about one minute, (and when cold it may be applied to the magnetic needle, as a collateral test for iron.

If there is no white, or yellow oxide, deposited on the coal, the specimen does not contain antimony, arsenic, bismuth, lead, tin, tellurium, or zinc, and those may be also erased from the list.

If you wish to examine for the rocks, do so now.

Quartz, scratches glass, before and after, strong ignition.
Lime, would now dissolve, or slack in water.
Magnesia and alumina, when moistened with a drop of the "solution of cobalt," and again strongly heated, will respectively show their characteristic flesh, or blue, colors.

If a white oxide deposits on the charcoal, at some distance from the test sample, it will be from antimony, arsenic, or tellurium.

Antimony, has a pleasant flower-like odor, arsenic, a disagreeable garlic stink; and the oxide of tellurium, will burn off, with a green flame, before that from the blowpipe.

If the oxide on the charcoal, is white, and close to the test sample, it is produced from tin.

If the oxide is yellow, when hot; and white, when cold; it is that of zinc.

The oxide of tin when moistened with "solution of cobalt," and re-heated before blowpipe, becomes of a greenish blue color; whilst the oxide of zinc, when thus treated changes to a bright green.

If the oxide on the charcoal is yellow, it is either from lead or bismuth.

Smelt on charcoal with carbonate of soda, and these minerals will be thus reduced to metals. Bismuth is very brittle, and lead very ductile, under the hammer.

You have now thoroughly tested for all but chlorine, copper, mercury, and sulphur.

Copper *was alluded to as coloring the first bead of carbonate of soda, but it may be now further tested and more effectually reduced on charcoal, when fluxed with say, equal parts of carbonate of soda and sugar, to irregular nuggets of red metal.*

It may be also detected in very small quantities when it has been first roasted in flame, then moistened with hydro-chloric acid, and re-flamed; as it first gives the blue flame, from the chlorine of the acid, then finishes with the beautiful green flame of copper.

Chlorine. *Fuse in the platinum wire a bead of microcosmic salt, with as much oxide of copper (or any copper ore thus oxidized) as it will absorb, then add the liquid or solid, that is to be tested, and place it into or before the flame; if chlorine is present it will soon show its characteristic blue.*

Sulphur. *Lay the first bead formed with carbonate of soda, or any other of the slags from the smeltings with that flux, on a moistened silver coin, and if the ore is a sulphuret, it will, by forming the soluble sulphate of soda, stain the bright silver, from brown to black, according to the quantity of sulphur present, or time given for the discoloration.*

Mercury. *Place a small piece of the raw ore, on a gold or copper coin, and impinge the flame from the blowpipe thereon, for a few seconds, so that the heated current, beyond the test sample, may pass close down upon the cold coin, when—if it be an ore of mercury—its fume will condense and amalgamate the surface of the metal, which can be more distinctly observed, after the coin has been rubbed with a wet finger.*

The coin may be again cleaned by warmth.

Thus, the qualitative analysis of the profitable base minerals may be readily and thoroughly completed, by men knowing nothing of minerals *at sight*, and the particular metal or metals found, may be then assayed for correct quantity, by either of the convenient modes.

The short abstract statement of operations for testing by the above mode, as given beneath, may be easily remembered.

1. Test, with carbonate of soda in platinum loop, for *colored beads*, of chromium, manganese, copper and lead.

2. Test, in similar manner with borax, for *colored beads*, from iron, and nickel; and also look for *collateral amethyst color*, of manganese.

3. Test, on charcoal, for iron, *by the magnetic needle;* for the oxides of antimony, arsenic, bismuth, lead, tin, tellurium, and zinc, by their *colors*, etc., etc.; and for the rocks, of quartz *by hardness*, lime *by its solubility*, and of magnesia and alumina *by the flesh and blue colors produced by "nitrate of cobalt" solution.*

4. Test for copper, by *actual reduction*, and *color of its flame when dissolved in hydro-chloric acid;* for chlorine, by a copper saturated bead of microcosmic salt, *by its blue flame;* for sulphur, by fusion with carbonate of soda, and dissolving the mass on a silver coin, *by its brown color;* and for mercury, by hot blast to the sample when placed on a gold or copper coin, *by its amalgamation.*

A NEW AND EFFECTUAL MODE, FOR TESTING AND ASSAYING SILVER ORES, AND CONCENTRATED AURIFEROUS QUARTZ; BY COMMON BLOW-PIPE.

There is no easily performed, quick, and reliable test, for *low-grade* silver ores, or for gold in *sulphuret of iron*, or even *small quantities of, free gold*, in quartz, short of the actual assay by smelting and cupellation; so that any more ready means for obtaining such assays, without cumbrous and expensive furnaces, will naturally be of immense value for explorers, not fully educated in mineralogy.

The assaying machine, described in this work, was especially contrived for the traveling purposes of prospectors, but its cost prevents general use, and as the system followed in books, for the assaying of silver by common blow-pipe, requires much skill and practice, I now give the far easier, and much better method, taught my pupils, which they have not only more readily executed, but invariably preferred.

ASSAYING OF SILVER ORES, BY COMMON BLOW-PIPE.

1. Select, or cut to form, a cubical, or cylindrical piece of solid pine or willow charcoal, about *one inch and a half* in diameter, and drill or sink a round *half-inch* shaft, one inch deep, in the *centre* of one of its facets; and then drill or drive a *quarter inch* transverse blast hole or tunnel, from one of its sides, to communicate therewith, so that the *bottom* of this tunnel shall enter, at a *quarter inch* above the bottom of the shaft.

2. Take about five grains of the sample, as carefully averaged by the method described at page 121, and after reducing it to an impalpable powder, weigh out *two grains* for the assay (which is twice the quantity that can be treated by the old method.)

3. Weigh *six grains of litharge*, (a universal flux for all the matrices) and intimately mix it with the two grains of ore.

4. Cast or brush this mixture down to the bottom of the shaft, into the charcoal.

5. Weigh *twelve grains* of test lead, and drop it down upon the previously fluxed ore, so that it may cover it entirely, and still leave a small passage over it from the tunnel to the shaft.

6. Trim your wick, fill the lamp with the best olive oil, and see that a superlatively good flame is produced.

7. Now take the charcoal into your left hand, and after inclining the *shaft* towards the eye, and the tunnel to the *wick*, blow a *gentle blast* over the wick, just so that the whole flame may pass downwards from the blow-pipe into the *tunnel* and up through the shaft, for some two or three minutes.

8. As soon as the litharge waxes over the surface of the sample, it is

secure from all danger of loss, and all your attention must be devoted to producing the greatest possible heat, by a proper strength of blast.

About ten minutes is generally required, for the completion of smelting, under *well directed continuous* flame, and suitable oscillation of the assay, but the novice will not be able to effect it in less than fifteen minutes, as he must occasionally stop the blast to breathe, which (unlike the old, voluminously fluxed, open, method) he is by this closely covered mode, enabled to do.

Those who cannot blow continuously, will find, that if towards the end of the process, a piece of charcoal, about the size of a pea, be placed in the shaft, the radiation or loss of heat will be but little during breathing time.

9. Allow the assay to get *quite cold*, cut out the slag and metal button, fold it in a piece of rag, place it on some hard support, and hit it once or twice with a hammer, or hard stone, to clear the slag away, so that the button may be brushed quite clean for cupellation.

10. Take the same or another piece of charcoal and scoop out with your knife, a ragged hollow, on one of its sides, about an inch in diameter and a half inch deep, which ram full of fine moistened bone ash, and compress the surface to a suitable concave, with a tea spoon or other properly shaped smooth instrument. Then slowly dry the ash by a fire.

11. When quite dry it may be held against the flame of the blow-pipe, brought to a red heat, and the smelted button quickly placed thereon for refinement, by oxidation, as follows.

12. Hold the supported metal in the hottest reducing flame from the blow-pipe until the metal is thoroughly fluid and almost white hot, then withdraw it a very little, so that the *point* of the *blue oxidizing flame*, may but *just reach the front* of the button. Great care must be taken to regulate the flame at suitable distance at this stage of the process, for although the flame must be kept for oxidizing, the heat should also be sufficient to keep the metal *quite molten*, and the bone ash *hot enough to absorb* the oxides of the base metals.

A little practice will enable you to perform *in this manner*, these operations of smelting and cupellation, for the assay not being encumbered with massive cartridge and borax, but mixed with this fusible, heavy, compact flux, and thus enclosed, as if in an actual furnace, the smelting can be much better effected; whilst the oxidation can also be accomplished far easier by any one, on the charcoal, than when the bone-ash is enclosed in the cold iron moulds recommended in books. No expensive tools are required for this method.

ASSAYING OF GOLD—BY COMMON BLOW-PIPE.

Take from the finely pulverized sample of quartz say two hundred grains, which carefully concentrate by water in the manner recommended in Chapter III, Section III; and you will generally find that the weight of the dried auriferous residue, will be less than the two grains required for this mode of assay. A little pure muriatic acid may be sometimes used to great advantage to pass away the base metals in solution, when the sufficiently reduced residue, after having been washed in water and dried, can be *fluxed and assayed as just described for silver ores.* For roasting sulphurets by blow-pipe, see page 311.

For methods of weighing the buttons and calculation of value per ton, of silver and gold assays, see page 242.

UNITED STATES MINING LAWS

AND

REGULATIONS THEREUNDER.

[FROM OFFICIAL COPY.]

AN ACT TO PROMOTE THE DEVELOPMENT OF THE MINING RESOURCES OF THE UNITED STATES.—APPROVED MAY 10, 1872.

Be it enacted by the Senate and House of Representatives of the United States of America in Congress assembled, That all valuable mineral deposits in lands belonging to the United States, both surveyed and unsurveyed, are hereby declared to be free and open to exploration and purchase, and the lands in which they are found to occupation and purchase, by citizens of the United States and those who have declared their intention to become such, under regulations prescribed by law, and according to the local customs or rules of miners, in the several mining-districts, so far as the same are applicable and not inconsistent with the laws of the United States.

SEC. 2. That mining-claims upon veins or lodes of quartz or other rock in place bearing gold, silver, cinnabar, lead, tin, copper, or other valuable deposits heretofore located, shall be governed as to length along the vein or lode by the customs, regulations, and laws in force at the date of their location. A mining-claim located after the passage of this act, whether located by one or more persons, may equal, but shall not exceed, one thousand five hundred feet in length along the vein or lode; but no location of a mining-claim shall be made until the discovery of the vein or lode within the limits of the claim located. No claim shall extend more than three hundred feet on each side of the middle of the vein at the surface, nor shall any claim be limited by any mining regulation to less than twenty-five feet on each side of the middle of the vein at the surface, except where adverse rights existing at the passage of this act shall render such limitation necessary. The end-lines of each claim shall be parallel to each other.

SEC. 3. That the locators of all mining locations heretofore made, or which shall hereafter be made, on any mineral vein, lode, or ledge, situated on the public domain, their heirs and assigns, where no adverse claim exists at the passage of this act, so long as they comply with the laws of the United States, and the State, territorial, and local regulations not in conflict with said laws of the United States governing their possessory title, shall have the exclusive right of possession and enjoyment of all the surface included within the lines of their locations, and of all veins, lodes, and ledges throughout their entire depth, the top of apex of which lies inside of such surface-lines extended downward vertically, although such veins, lodes, or ledges may so far depart from a perpendicular in their course downward as to extend outside the vertical side-lines of

said surface locations: *Provided*, That their right of possession to such outside parts of such veins or ledges shall be confined to such portions thereof as lie between vertical planes drawn downward as aforesaid, through the end-lines of their locations, so continued in their own direction that such planes will intersect such exterior parts of said veins or ledges: *And provided further*, That nothing in this section shall authorize the locator or possessor of a vein or lode which extends in its downward course beyond the vertical lines of his claim to enter upon the surface of a claim owned or possessed by another.

SEC. 4. That where a tunnel is run for the development of a vein or lode, or for the discovery of mines, the owners of such tunnel shall have the right of possession of all veins or lodes within three thousand feet from the face of such tunnel on the line thereof, not previously known to exist, discovered in such tunnel, to the same extent as if discovered from the surface; and locations on the line of such tunnel of veins or lodes not appearing on the surface, made by other parties after the commencement of the tunnel, and while the same is being prosecuted with reasonable diligence, shall be invalid; but failure to prosecute the work on the tunnel for six months shall be considered as an abandonment of the right to all undiscovered veins on the line of said tunnel.

SEC. 5. That the miners of each mining district may make rules and regulations not in conflict with the laws of the United States, or with the laws of the State or Territory in which the district is situated, governing the location, manner of recording, amount of work necessary to hold possession of a mining claim subject to the following requirements: The location must be distinctly marked on the ground so that its boundaries can be readily traced. All records of mining-claims here after made shall contain the name or names of the locators, the date of the location, and such a description of the claim or claims located by reference to some natural object or permanent monument as will identify the claim. On each claim located after the passage of this act, and until a patent shall have been issued therefor, not less than one hundred dollars' worth of labor shall be performed or improvements made during each year. On all claims located prior to the passage of this act, ten dollars' worth of labor shall be performed or improvements made each year for each one hundred feet in length along the vein until a patent shall have been issued therefor; but where such claims are held in common, such expenditure may be made upon any one claim; and upon a failure to comply with these conditions, the claim or mine upon which such failure occurred shall be open to re-location in the same manner as if no location of the same had ever been made: *Provided*, That the original locators, their heirs, assigns, or legal representatives, have not resumed work upon the claim after such failure and before such location. Upon the failure of any one of several co-owners to contribute his proportion of the expenditures required by this act, the co-owners who have performed the labor or made the improvements, may, at the expiration of the year, give such delinquent co-owner personal notice in writing or notice by publication in the newspaper published nearest the claim, for at least once a week for ninety days, and if at the expiration of ninety days after such notice in writing or by publication such delinquent should fail or refuse to contribute his proportion to comply with this Act, his interest in the claim shall become the property of his co-owners, who have made the required expenditures.

SEC. 6. That a patent for any land claimed and located for valuable deposits may be obtained in the following manner: Any person, association, or corporation authorized to locate a claim under this Act, having claimed and located a piece of land for such purposes, who has, or have, complied with the terms of this Act, may file in the proper land-office an application for a patent, under oath, showing such compliance, together with a plat and field-notes claim or claims in common, made by or under the direction of the United States Surveyor-General, showing accurately the boundaries of the claim or claims, which shall be distinctly marked by monuments on the ground, and shall post a copy of such plat, together with a notice of such application for a patent, in a conspicuous place on the land embraced in such plat previous to the filing of the application for a patent, and shall file an affidavit of at least two persons, that such notice has been duly posted as aforesaid, and shall file a copy of said notice in such land-office, and shall thereupon be entitled to a patent for said

land, in the manner following: The register of the land-office, upon the filing of such application, plat, field-notes, notices, and affidavits, shall publish a notice that such application has been made, for the period of sixty days, in a newspaper to be by him designated as published nearest to said claim; and he shall also post such notice in his office for the same period. The claimant at the time of filing this application, or at any time thereafter, within the sixty days of publication, shall file with the Register a certificate of the United States Surveyor-General that five hundred dollars' worth of labor has been expended or improvements made upon the claim by himself or grantors; that the plat is correct, with such further description by such reference to natural objects or permanent monuments as shall identify the claim, and furnish an accurate description, to be incorporated in the patent. At the expiration of the sixty days of publication the claimant shall file his affidavit, showing that the plat and notice have been posted in a conspicuous place on the claim during said period of publication. If no adverse claim shall have been filed with the Register and the Receiver of the proper land-office at the expiration of the sixty days of publication it shall be assumed that the applicant is entitled to a patent, upon the payment to the proper officer of five dollars per acre, and that no adverse claim exists; and thereafter no objection from third parties to the issuance of a patent shall be heard, except it be shown that the applicant has failed to comply with this Act.

Sec. 7. That where an adverse claim shall be filed during the period of publication, it shall be upon oath of the person or persons making the same, and shall show the nature, boundaries, and extent of such adverse claim, and all proceedings, except the publication of notice and making and filing of the affidavit thereof, shall be stayed until the controversy shall have been settled or decided by a Court of competent jurisdiction, or the adverse claim waived. It shall be the duty of the adverse claimant, within thirty days after filing his claim, to commence proceedings in a Court of competent jurisdiction, to determine the question of the right of possession, and prosecute the same with reasonable diligence to final judgment; and a failure so to do shall be a waiver of his adverse claim. After such judgment shall have been rendered, the party entitled to the possession of the claim, or any portion thereof, may, without giving further notice, file a certified copy of the judgment-roll with the Register of the land-office, together with the certificate of the Surveyor-General that the requisite amount of labor has been expended, or improvements thereon, and the description required in other cases, and shall pay to the Receiver five dollars per acre for his claim, together with the proper fees, whereupon the whole proceedings and the judgment-roll shall be certified by the Register to the Commissioner of the General Land Office, and a patent shall issue thereon for the claim, or such portion thereof as the applicant shall appear, from the decision of the Court, to rightly possess. If it shall appear, from the decision of the Court, that several parties are entitled to separate and different portions of the claim, each party may pay for his portion of the claim, with the proper fees, and file the certificate and description by the Surveyor-General, whereupon the Register shall certify the proceedings and judgment-roll to the Commissioner of the General Land Office, as in the preceding case, and patents shall issue to the several parties according to their respective rights. Proof of citizenship under this Act, or the Acts of July twenty-sixth, eighteen hundred and sixty-six, and July ninth, eighteen hundred and seventy, in the case of an individual, may consist of his own affidavit thereof and in case of an association of persons unincorporated, of the affidavit of their authorized agent made on his own knowledge or upon information and belief, and in case of a corporation organized under the laws of the United States, or of any State or Territory of the United States, by the filing of a certified copy of their charter or certificate of incorporation; and nothing herein contained shall be construed to prevent the alienation of the title conveyed by a patent for a mining claim to any person whatever.

Sec. 8. That the description of vein or lode claims, upon surveyed lands, shall designate the location of the claim with reference to the lines of the public surveys, but need not conform therewith; but where a patent shall be issued as aforesaid for claims upon unsurveyed lands, the Surveyor-General, in extending

the surveys, shall adjust the same to the boundaries of such patented claim, according to the plat or description thereof, but so as in no case to interfere with or change the location of any such patented claim.

SEC. 9. That sections one, two, three, four and six of an Act entitled "An Act granting the right of way to ditch and canal owners over the public lands, and for other purposes," approved July twenty-sixth, eighteen hundred and sixty-six, are hereby repealed, but such repeal shall not affect existing rights. Applications for patents for mining claims now pending may be prosecuted to a final decision in the General Land Office; but in such cases where adverse rights are not affected thereby, patents may issue in pursuance of the provisions of this Act; and all patents for mining claims heretofore issued under the Act of July twenty-sixth, eighteen hundred and sixty-six, shall convey all the rights and privileges conferred by this Act where no adverse rights exist at the time of the passage of this Act.

SEC. 10. That the Act entitled "An Act to amend an Act granting the right of way to ditch and canal owners over the public lands, and for other purposes," approved July ninth, eighteen hundred and seventy, shall be and remain in full force, except as to the proceedings to obtain a patent, which shall be similar to the proceedings prescribed by sections six and seven of this Act for obtaining patents to vein or lode claims; but where said placer claims shall be upon surveyed lands, and conform to legal subdivisions, no further survey or plat shall be required, and all placer mining claims hereafter located shall conform as near as practicable with the United States system of public land surveys, and the rectangular subdivisions of such surveys, and no such location shall include more than twenty acres for each individual claimant, but where placer claims cannot be conformed to legal subdivisions, survey and plat shall be made as on unsurveyed lands: *Provided*, That proceedings now pending may be prosecuted to their final determination under existing laws; but the provisions of this Act, when not in conflict with existing laws, shall apply to such cases: *And provided also*, That where by the segregation of mineral land in any legal subdivision, a quantity of agricultural land less than forty acres remains, said fractional portion of agricultural land may be entered by any party qualified by law for homestead or pre-emption purposes.

SEC. 11. That where the same person, association or corporation is in possession of a placer claim, and also a vein or lode included within the boundaries thereof, application shall be made for a patent for the placer claim, with the statement that it includes such vein or lode, and in such case (subject to the provisions of this Act and the Act entitled "An Act to amend an Act granting the right of way to ditch and canal owners over the public lands, and for other purposes," approved July ninth, eighteen hundred and seventy) a patent shall issue for the placer claim, including such vein or lode, upon the payment of five dollars per acre for such vein or lode claim, and twenty-five feet of surface on each side thereof. The remainder of the placer claim, or any placer claim not embracing any vein or lode claim, shall be paid for at the rate of two dollars and fifty cents per acre, together with all costs of proceedings; and where a vein or lode, such as is described in the second section of this Act, is known to exist within the boundaries of a placer claim, an application for a patent for such placer claim, which does not include an application for the vein or lode claim, shall be construed as a conclusive declaration that the claimant of the placer claim has no right to the possession of the vein or lode claim; but where the existence of a vein or lode in a placer claim is not known, a patent for the placer claim shall convey all valuable mineral and other deposits within the boundaries thereof.

SEC. 12. That the Surveyor-General of the United States may appoint in each land district containing mineral lands as many competent surveyors as shall apply for appointment to survey mining claims. The expenses of the survey of vein or lode claims and the survey and subdivision of placer claims into smaller quantities than one hundred and sixty acres, together with the cost of publication of notices, shall be paid by the applicants, and they shall be at liberty to obtain the same at the most reasonable rates, and they shall also be at liberty to employ any United States Deputy Surveyor to make the survey.

The Commissioner of the General Land Office shall also have power to establish the maximum charges for surveys and publication of notices under this Act; and, in case of excessive charges for publication, he may designate any newspaper published in a land district where mines are situated, for the publication of mining notices in such district, and to fix the rates to be charged by such paper; and to the end that the Commissioner may be fully informed upon the subject, each applicant shall file with the Register a sworn statement of all charges and fees paid by said applicant for publication and surveys, together with all fees and money paid the Register and the Receiver of the General Land Office. The fees of the Register and the Receiver shall be five dollars each for filing and acting upon each application for patent or adverse claim filed, and they shall be allowed the amount fixed by law for reducing testimony to writing, when done in the land office, such fees and allowances to be paid by the respective parties; and no other fees shall be charged by them in such cases. Nothing in this Act shall be construed to enlarge or affect the rights of either party in regard to any property in controversy at the time of the passage of this Act, or of the Act entitled "An Act granting the right of way to ditch and canal owners over public lands, and for other purposes," approved July twenty-sixth, eighteen hundred and sixty-six, nor shall this Act affect any right acquired under said Act; and nothing in this Act shall be construed to repeal, impair, or in any way affect the provisions of the Act entitled "An Act granting to A. Sutro the right of way and other privileges to aid in the construction of a draining and exploring tunnel to the Comstock lode, in the State of Nevada," approved July twenty-fifth, eighteen hundred and sixty-six.

SEC. 13. That all affidavits required to be made under this Act, or the Act of which it is amendatory, may be verified before any officer authorized to administer oaths within the land district where the claims may be situated, and all testimony and proofs may be taken before any such officer, and when duly certified by the officer taking the same, shall have the same force and effect as if taken before the Register and Receiver of the land office. In cases of contest as to the mineral or agricultural character of land, the testimony and proofs may be taken as herein provided, on personal notice of at least ten days to the opposing party; or if said party cannot be found, then by publication of at least once a week for thirty days in a newspaper, to be designated by the Register of the land office as published nearest to the location of such land; and the Register shall require proof that such notice has been given.

SEC. 14. That where two or more veins intersect or cross each other, priority of title shall govern, and such prior location shall be entitled to all ore or mineral contained within the space of intersection: *Provided, however*, That the subsequent location shall have the right of way through said space of intersection for the purposes of the convenient working of the said mine: *And provided also*, That where two or more veins unite, the oldest or prior location shall take the vein below the point of union, including all the space of intersection.

SEC. 15. That where non-mineral land not contiguous to the vein or lode is used or occupied by the proprietor of such vein or lode for mining or milling purposes, such non-adjacent surface ground may be embraced and included in an application for such vein or lode, and the same may be patented therewith, subject to the same preliminary requirements as to survey and notice as are applicable under this Act to veins or lodes: *Provided*, That no location hereafter made of such non-adjacent land shall exceed five acres, and payment for the same must be made at the same rate as fixed by this Act for the superficies of the lode. The owner of a quartz mill or reduction works not owning a mine in connection therewith may also receive a patent for his mill site, as provided in this section.

SEC. 16. That all Acts or parts of Acts inconsistent herewith are hereby repealed: *Provided*, That nothing contained in this Act shall be construed to impair in any way rights or interests in mining property acquired under existing laws.

Approved May 10, 1872.

Instructions from the General Land Office, June 10, 1872.

MINERAL LANDS OPEN TO EXPLORATION, OCCUPATION AND PURCHASE.

1. It will be perceived that the first section of said Act leaves the mineral lands in the public domain, surveyed or unsurveyed, open to exploration, occupation and purchase by all citizens of the United States and all those who have declared their intention to become such.

STATUS OF LODE CLAIMS PREVIOUSLY LOCATED.

2. By an examination of the several sections of the foregoing Act it will be seen that the *status* of lode claims located *previous* to the date thereof is not changed with regard to their *extent along the lode or width of surface*, such claims being restricted and governed both as to their *lateral and linear* extent by the State, Territorial, or local laws, customs or regulations which were in force in the respective districts at the date of such locations in so far as the same did not conflict with the limitations fixed by the mining statute of July 26, 1866.—(14 Stat., 251.)

3. Mining rights acquired under such previous locations are, however, enlarged by said Act of May 10, 1872, in the following respect, viz: The locators of all such previously taken veins or lodes, their heirs and assigns, so long as they comply with the laws of Congress and with State, Territorial or local regulations not in conflict therewith, governing mining claims, are invested by said Act with the exclusive possessory right of all the surface included within the lines of their locations, and of all veins, lodes or ledges throughout their entire depth, the top or apex of which lies inside of such surface lines extended downward vertically, although such veins, lodes or ledges may so far depart from a perpendicular in their course downward as to extend outside the vertical side-lines of such locations at the surface, it being expressly provided, however, that the right of possession to such outside parts of said veins or ledges shall be confined to such portions thereof as lie between vertical planes drawn downward as aforesaid, through the end lines of their locations so continued in their own direction that such planes will intersect such exterior parts of such veins, lodes or ledges; no right being granted, however, to the claimant of such outside portion of a vein or ledge to enter upon the surface location of another claimant.

4. It is to be distinctly understood, however, that the law limits the possessory right to veins, lodes or ledges other than the one named in the original location, to such as were not *adversely claimed at the date of said Act of May* 10, 1872, and that where such other vein or ledge was so adversely claimed at that date, the right of the party so adversely claiming is in no way impaired by said Act.

5. From and after the date of said Act of Congress, in order to hold the possessory title to a mining claim *previously located*, and for which a patent has not been issued, the law requires that *ten dollars* shall be expended annually in labor or improvements on each claim of *one hundred feet* on the course of the vein or lode until a patent shall have been issued therefor; but where a number of such claims are held in common upon the same vein or lode, the aggregate expenditure that would be necessary to hold all the claims, at the rate of ten dollars per hundred feet, may be made upon any one claim; a failure to comply with this requirement in any one year subjecting the claim upon which such failure occurred to re-location by other parties, the same as if no previous location thereof had ever been made, unless the claimants under the original location shall have resumed work thereon after such failure and before such re-location.

6. Upon the failure of any one of several co-owners of a vein, lode or ledge which has not been patented, to contribute his proportion of the expenditure necessary to hold the claim or claims so held in ownership in common, the co-owners who have performed the labor, or made the improvements as required by said act, may, at the expiration of the year, give such delinquent co-owner personal notice in writing, or notice by publication in the newspaper published nearest the claim, for at least once a week for ninety days; and if upon the expiration of ninety days after such notice in writing, or upon the expiration of one hundred and eighty days after the first newspaper publication of notice, the delinquent co-owner shall have failed to contribute his proportion to meet such expenditure or improvements, his interest in the claim by law passes to his co-owners who have made the expenditures or improvements as aforesaid.

PATENTS FOR VEINS OR LODES HERETOFORE ISSUED.

7. Rights under patents for veins or lodes heretofore granted under previous legislation of Congress, are enlarged by this Act so as to invest the patentee, his heirs or assigns, with title to all veins, lodes or ledges throughout their entire depth, the top or apex of which lies within the end and side boundary lines of the claim on the surface, as patented, extended downward vertically, although such veins, lodes or ledges may so far depart from a perpendicular in their course downward as to extend outside the vertical side-lines of the claim at the surface. The right of possession to such outside parts of such veins or ledges to be confined to such portions thereof as lie between vertical planes drawn downward through the end-lines of the claim at the surface, so continued in their own direction that such planes will intersect such exterior parts of such veins or ledges; it being expressly provided, however, that all veins, lodes or ledges the top or apex of which lies inside such surface locations, *other* than the one named in the patent, which were *adversely claimed* at the date of said Act, are excluded from such conveyance by patent.

8. Applications for patents for mining claims pending at the date of the Act of May 10, 1872, may be prosecuted to final decision in the General Land Office, and where no adverse rights are affected thereby, patents will be issued, in pursuance of the provisions of said Act.

MANNER OF LOCATING CLAIMS ON VEINS OR LODES AFTER THE PASSAGE OF THE ACT OF MAY 10, 1872.

9. From and after the date of said Act, any person who is a citizen of the United States, or who has declared his intention to become a citizen, may locate, record and hold a mining claim of *fifteen hundred linear feet* along the course of any mineral vein or lode subject to location; or an association of persons, severally qualified as above, may make joint location of such claim of *fifteen hundred feet*, but in no event can a location of a vein or lode made subsequent to the Act exceed fifteen hundred feet along the course thereof, whatever may be the number of persons composing the association.

10. With regard to the extent of surface-ground adjoining a vein or lode, and claimed for the convenient working thereof, the Act provides that the lateral extent of locations of veins or lodes, made after its passage, shall in no case *exceed three hundred feet on each side of the vein at the surface*, and that no such surface rights shall be limited by any mining regulations to less than twenty-five feet on each side of the middle of the vein at the surface, except where adverse rights existing at the date of said Act may render such limitation necessary, the end lines of such claims to be in all cases parallel to each other.

11. By the foregoing it will be perceived that no lode-claim located after the date of said Act can exceed a parallelogram fifteen hundred feet in length by six hundred feet in width, but whether surface-ground of that width can be taken, depends upon the local regulations or State or Territorial laws in force in the several mining districts; and that no such local regulations or State or Territorial laws shall limit a vein or lode claim to less than 1,500 feet along the course thereof, whether the location is made by one or more persons, nor can

surface rights be limited to less than fifty feet in width, unless adverse claims existing on the 10th day of May, 1872, render such lateral limitation necessary.

12. It is provided in said Act that the miners of each district may make rules and regulations not in conflict with the laws of the United States, or of the State or Territory in which such districts are respectively situated, governing the location, manner of recording, and amount of work necessary to hold possession of a claim. It likewise requires that the location must be so distinctly marked on the ground that its boundaries may be readily traced. This is a very important matter, and locators cannot exercise too much care in defining their locations at the outset, inasmuch as the law requires that all records of mining locations made subsequent to its passage, shall contain the name or names of the locators, the date of the location, and such a *description of the claim or claims* located, by reference to some natural object or permanent monument, as will identify the claim.

13. The said Act requires that no lode claim can be recorded until after the discovery of a vein or lode within the limits of the ground claimed ; the object of which provision is evidently to prevent the encumbering of the district mining records with useless locations before sufficient work has been done thereon to determine whether a vein or lode has really been discovered or not.

14. The claimant should therefore, prior to recording his claim, unless the vein can be traced upon the surface, sink a shaft, or run a tunnel or drift, to a sufficient depth therein to discover and develop a mineral-bearing vein, lode, or crevice ; should determine, if possible, the general course of such vein in either direction from the point of discovery, by which direction he will be governed in marking the boundaries of his claim on the surface, and should give the course and distance as nearly as practicable from the discovery-shaft on the claim, to some permanent, well-known points or objects, such, for instance, as stone monuments, blazed trees, the confluence of streams, point of intersection of well-known gulches, ravines, or roads, prominent buttes, hills, etc., which may be in the immediate vicinity, and which will serve to perpetuate and fix the *locus* of the claim and render it susceptible of identification from the description thereof given in the record of locations in the district.

15. In addition to the foregoing data, the claimant should state the names of adjoining claims, or if none adjoin, the relative positions of the nearest claims ; should drive a post or erect a monument of stones at each corner of his surface-ground, and at the point of discovery or discovery-shaft, should fix a post, stake, or board, upon which should be designated the name of the lode, the name or names of the locators, the number of feet claimed, and in which direction from the point of discovery, it being essential that the location notice filed for record, in addition to the foregoing description should state whether the entire claim of fifteen hundred feet is taken on one side of the point of discovery, or whether it is partly upon one and partly upon the other side thereof, and in the latter case, how many feet are claimed upon each side of such discovery-point.

16. Within a reasonable time, say twenty days after the location shall have been marked on the ground, notice thereof, accurately describing the claim in manner aforesaid, should be filed for record with the proper recorder of the district, who will thereupon issue the usual certificate of location.

17. In order to hold the possessory rights to a claim of fifteen hundred feet of a vein or lode located as aforesaid, the Act requires that until a patent shall have been issued therefor, not less than one hundred dollars' worth of labor shall be performed or improvements made thereon during each year, in default of which the claim will be subject to re-location by any other party having the necessary qualifications, unless the original locator, his heirs, assigns, or legal representatives, have resumed work thereon after such failure and before such re-location.

18. The importance of attending to these details in the matter of location, labor and expenditure will be the more readily perceived when it is understood that a failure to give the subject proper attention, may invalidate the claim.

TUNNEL RIGHTS.

19. The fourth section of the Act provides that where a tunnel is run for the development of a vein or lode, or for the discovery of mines, the owners of such tunnel shall have the right of possession of all veins or lodes within three thousand feet from the face of such tunnel on the line thereof, not previously known to exist, discovered in such tunnel, to the same extent as if discovered from the surface; and locations on the line of such tunnel of veins or lodes not appearing on the surface, made by other parties after the commencement of the tunnel, and while the same is being prosecuted with reasonable diligence, shall be invalid; but failure to prosecute the work on the tunnel for six months shall be considered as an abandonment of the right to all undiscovered veins or lodes on the line of said tunnel.

20. The effect of this section is simply to give the proprietors of a mining tunnel run in good faith the possessory right to fifteen hundred feet of any blind lodes cut, discovered or intersected by such tunnel, which were not previously known to exist, within three thousand feet from the face or point of commencement of such tunnel, and to prohibit other parties, after the commencement of the tunnel, from prospecting for and making locations of lodes on the *line thereof* and within said distance of three thousand feet, unless such lodes appear upon the surface or were previously known to exist.

21. The term "face," as used in said section, is construed and held to mean the first working face formed in the tunnel, and to signify the point at which the tunnel actually enters cover, it being from this point that the three thousand feet are to be counted, upon which prospecting is prohibited as aforesaid.

22. To avail themselves of the benefits of this provision of law, the proprietors of a mining tunnel will be required, at the time they enter cover as aforesaid, to give proper notice of their tunnel location, by erecting a substantial post, board, or monument, at the face or point of commencement thereof, upon which should be posted a good and sufficient notice, giving the names of the parties or company claiming the tunnel right; the actual or proposed course or direction of the tunnel; the hight and width thereof, and the course or distance from such face or point of commencement to some permanent well known objects in the vicinity by which to fix and determine the *locus* in manner heretofore set forth applicable to locations of veins or lodes, and at the time of posting such notice they shall, in order that miners or prospectors may be enabled to determine whether or not they are within the lines of the tunnel, establish the boundary lines thereof by stakes or monuments placed along such lines at proper intervals, to the terminus of the three thousand feet from the face or point of commencement of the tunnel, and the lines so marked will define and govern as to the specific boundaries within which prospecting for lodes not previously known to exist is prohibited while work on the tunnel is being prosecuted with reasonable diligence.

23. At the time of posting notice and marking out the lines of the tunnel as aforesaid, a full and correct copy of such notice of location defining the tunnel claim must be filed for record with the mining recorder of the district, to which notice must be attached the sworn statement or declaration of the owners, claimants, or projectors of such tunnel, setting forth the facts in the case; stating the amount expended by themselves and their predecessors in interest in prosecuting work thereon; the extent of the work performed, and that it is *bona fide* their intention to prosecute work on the tunnel so located and described with reasonable diligence for the development of a vein or lode, or for the discovery of mines, or both, as the case may be.

24. This notice of location must be duly recorded, and, with the said sworn statement attached, kept on the recorder's files for future reference.

25. By a compliance with the foregoing, much needless difficulty will be avoided, and the way for the adjustment of legal rights acquired in virtue of said fourth section of the Act will be made much more easy and certain.

26. This office will take particular care that no improper advantage is taken of this provision of law by parties making or professing to make tunnel loca-

tions, ostensibly for the purpose named in the statute, but really for the purpose of monopolizing the lands lying in front of their tunnels to the detriment of the mining interests and to the exclusion of *bona fide* prospectors or miners; but will hold such tunnel claimants to a strict compliance with the terms of the Act; and as *reasonable diligence* on their part in prosecuting the work is one of the essen tial conditions of their implied contract, negligence or want of due diligence will be construed as working a forfeiture of their right to all undiscovered veins on the line of such tunnel.

MANNER OF PROCEEDING TO OBTAIN GOVERNMENT TITLE TO VEIN OR LODE CLAIMS.

27. By the sixth section of said Act, authority is given for granting title for mines by patent from the Government, to any person, association or corporation having the necessary qualifications as to citizenship and holding the right of possession to a claim in compliance with law.

28. The claimant is required in the first place to have a correct survey of his claim made under authority of the Surveyor-General of the State or Territory in which the claim lies; such survey to show with accuracy the exterior surface boundaries of the claim, which boundaries are required to be distinctly marked by monuments on the ground.

29. The claimant is then required to post a copy of the plat of such survey in a conspicuous place upon the claim, together with notice of his intention to apply for a patent therefor, which notice will give the date of posting, the name of the claimant, the name of the claim, mine or lode; the mining district and county; whether the location is of record, and if so, where the record may be found; the number of feet claimed along the vein and the presumed direction thereof; the number of feet claimed along the lode in each direction from the point of discovery, or other well-defined place on the claim; the name or names of adjoining claimants on the same or other lodes; or if none adjoin, the names of the nearest claims, etc.

30. After posting the said plat and notice upon the premises, the claimant will file with the proper Register and Receiver a copy of such plat, and the field-notes of survey of the claim, accompanied by the affidavit of at least two credible witnesses that such plat and notice are posted conspicuously upon the claim, giving the date and place of such posting; a copy of the *notice* so posted to be attached to, and form a part of, said affidavit.

31. Attached to the field-notes so filed must be the sworn statement of the claimant that he has the possessory right to the premises therein described, in virtue of a compliance by himself (and by his grantors, if he claims by purchase) with the mining rules, regulations, and customs of the mining district, State, or Territory, in which the claim lies, and with the mining laws of Congress, such sworn statement to narrate briefly, but as clearly as possible, the facts constituting such compliance, the origin of his possession, and the basis of his claim to a patent.

32. This affidavit should be supported by appropriate evidence from the mining recorder's office as to his possessory right, as follows, viz: Where he claims to be a locator, a full, true, and correct copy of such location should be furnished, as the same appears upon the mining records; such copy to be attested by the seal of the Recorder, or if he has no seal, then he should make oath to the same being correct, as shown by his records; where the applicant claims as a locator in company with others, who have since conveyed their interests in the lode to him, a copy of the original record of location should be filed, together with an abstract of title from the proper Recorder, under seal or oath as aforesaid, tracing the co.ocator's possessory rights in the claim to such applicant for patent; where the applicant claims only as a purchaser for valuable consideration, a copy of the location record must be filed, under seal or upon oath as aforesaid, with an abstract of title certified as above by the proper Recorder, tracing the right of possession by a continuous chain of conveyances from the original locators to the applicant.

33. In the event of the mining records in any case having been destroyed by fire or otherwise lost, affidavit of the fact should be made, and secondary evidence of possessory title will be received, which may consist of the affidavit of the claimant, supported by those of any other parties cognizant of the facts relative to his location, occupancy, possession, improvements, &c.; and in such case of lost records, any deeds, certificates of location or purchase, or other evidence which may be in the claimant's possession, and tend to establish his claim, should be filed.

34. Upon the receipt of these papers the Register will, at the expense of the claimant, publish a notice of such application for the period of sixty days, in a newspaper published nearest to the claim, and will post a copy of such notice in his office for the same period.

35. The notices so published and posted must be as full and complete as possible, and embrace all the *data* given in the notice posted upon the claim.

36. Too much care cannot be exercised in the preparation of these notices, inasmuch as upon their accuracy and completeness will depend, in a great measure, the regularity and validity of the whole préceeding.

37. The claimant, either at the time of filing these papers with the Register, or at any time during the sixty days' publication, is required to file a certificate of the Surveyor-General that not less than five hundred dollars' worth of labor has been expended or improvements made upon the claim by the applicant or his grantors; that the plat filed by the claimant is correct; that the field-notes of the survey, as filed, furnish such an accurate description of the claim as will, if incorporated into a patent, serve to fully identify the premises, and that such reference is made there to natural objects or permanent monuments as will perpetuate and fix the *locus* thereof.

38. It will be the more convenient way to have this certificate indorsed by the Surveyor-General, both upon the patent and field-notes of survey filed by the claimant as aforesaid.

39. After the sixty days' period of newspaper publication has expired, the claimant will file his affidavit, showing that the plat and notice aforesaid remained conspicuously posted upon the claim sought to be patented during the said sixty day's publication.

40. Upon the filing of this affidavit the Register will, if no adverse claim was filed in his office during the period of publication, permit the claimant to pay for the land according to the area given in the plat and field-notes of survey aforesaid, at the rate of five dollars for each acre and five dollars for each fractional part of an acre, the Receiver issuing the usual duplicate receipt therefor; after which the whole matter will be forwarded to the Commissioner of the General Land Office and a patent issued thereon if found regular.

41. In sending up the papers in the case the Register must not omit certifying to the facts that the notice was posted in his office for the full period of sixty days, such certificate to state distinctly when such posting was done and how long continued

42. The consecutive series of numbers of mineral entries must be continued, whether the same are of lode or placer claims.

43. The Surveyor-General must continue to designate all surveyed mineral claims as heretofore by a progressive series of numbers, beginning with lot No. 37 in each township; the claim to be so designated at date of filing the plat, field-notes, etc., in addition to the local designation of the claim; it being required in all cases that the plat and field notes of the survey of a claim must, in addition to the reference to permanent objects in the neighborhood, describe the *locus* of the claim with reference to the lines of public surveys by a line connecting a corner of the claim with the nearest public corner of the United States surveys, unless such claim be on unsurveyed land at a remote distance from such public corner; in which latter case the reference by course and distance to permanent objects in the neighborhood will be a sufficient designation by which to fix the *locus* until the public surveys shall have been closed upon its boundaries.

ADVERSE CLAIMS.

44. The seventh section of the Act provides for adverse claims; fixes the time within which they shall be filed to have legal effect, and prescribes the manner of their adjustment.

45. Said section requires that the adverse claim shall be filed during the period of publication of notice; that it must be on the oath of the adverse claimant; and that it must show the "*nature*," the "*boundaries*" and the "*extent*" of the adverse claims.

46. In order that this section of the law may be properly carried into effect, the following is communicated for the information of all concerned.

47. An adverse mining claim must be filed with the Register of the same land office with whom the application for patent was filed, or in his absence with the Receiver, and within the sixty days' period of newspaper publication of notice.

48. The adverse notice must be duly sworn to before an officer authorized to administer oaths within the land district, or before the Register or Receiver; it will fully set forth the nature and extent of the interference or conflict; whether the adverse party claims as a purchaser for valuable consideration or as a locator; if the former, the original conveyance, or a duly certified copy thereof, should be furnished, or if the transaction was a mere verbal one, he will narrate the circumstances attending the purchase, the date thereof, and the amount paid, which facts should be supported by the affidavit of one or more witnesses, if any were present at the time, and if he claims as a locator he must file a duly certified copy of the location from the office of the proper Recorder.

49. In order that the "*boundaries*" and "*extent*" of the claim may be shown it will be incumbent upon the adverse claimant to file a plat showing his claim and its relative situation or position with the one against which he claims, so that the extent of the conflict may be the better understood. This plat must be made from an actual survey of the United States deputy surveyor, who will officially certify thereon to its correctness; and in addition there must be attached to such plat of survey a certificate or sworn statement by the surveyor as to the approximate value of the labor performed or improvements made upon the claim of the adverse party, and the plat must indicate the position of any shafts, tunnels, or other improvements, if any such exist upon the claim of the party opposing the application.

50. Upon the foregoing being filed within the sixty days as aforesaid, the Register, or in his absence the Receiver, will give notice in writing to *both parties* to the contest that such adverse claim has been filed, informing them that the party who filed the adverse claim will be required within thirty days from the date of such filing to commence proceedings in a Court of competent jurisdiction, to determine the question of right of possession, and to prosecute the same with reasonable diligence to final judgment, and that should such adverse claimant fail to do so, his adverse claim will be considered waived, and the application for patent be allowed to proceed upon its merits.

51. When an adverse claim is filed as aforesaid, the Register or Receiver will indorse upon the same the precise date of filing, and preserve a record of the date of notifications issued thereon; and thereafter all proceedings on the application for patent will be suspended, with the exception of the completion of the publication and posting of notices and plat, and the filing of the necessary proof thereof,until the controversy shall have been adjudicated in Court, or the adverse claim waived or withdrawn.

52. The proceedings after rendition of judgment by the Court in such case are so clearly defined by the Act itself as to render it unnecessary to enlarge thereon in this place.

PLACER CLAIMS.

53. The tenth section of the Act under consideration provides "that the Act entitled 'An Act to amend an Act granting the right of way to ditch and canal owners over the public lands, and for other purposes,' approved July 9, 1870, shall be and remain in full force, except as to the proceedings to obtain a patent, which shall be similar to the proceedings prescribed by sections six and

seven of this Act for obtaining patents for vein or lode claims, but where said placer claims shall be upon unsurveyed lands and conform to legal subdivisions, no further survey or plat shall be required, and all placer mining claims hereafter located shall conform, as nearly as practicable, with the United States system of public land surveys and the rectangular subdivisions of such surveys, and no such locations shall include more than twenty acres for each individual claimant; but where placer claims cannot be conformed to legal subdivisions, survey and plat shall be made as on unsurveyed lands," etc.

54. The proceedings for obtaining patents for veins or lodes having already been fully given, it will not be necessary to repeat them here; it being thought that careful attention thereto by applicants and the local officers will enable them to act understandingly in the matter and make such slight modifications in the notice, or otherwise, as may be necessary in view of the different nature of the two classes of claims, placer-claims being fixed, however, at two dollars and fifty cents per acre, or fractional part of an acre.

55. The twelfth and thirteenth sections of said Act of July 9, 1870, reads as follows:

SEC. 12. *And be it further enacted*, That claims, usually called "placers," including all forms of deposit, excepting veins of quartz, or other rocks in place, shall be subjected to entry and patent under this Act, under like circumstances and conditions, and upon similar proceedings, as are provided for vein or lode claims: *Provided*, That where the lands have been previously surveyed by the United States, the entry in its exterior limits shall conform to the legal subdivisions of the public lands, no further survey or plat in such case being required, and the lands may be paid for at the rate of two dollars and fifty cents per acre: *Provided further*, That legal subdivisons of forty acres may be subdivided into ten-acre tracts; and that two or more persons, or associations of persons, having contiguous claims of any size, although such claims may be less than ten acres each, may make joint entry thereof: *And provided further*, That no location of a placer claim, hereafter made, shall exceed one hundred and sixty acres for any one person or association of persons, which location shall conform to the United States surveys; and nothing in this section contained shall defeat or impair any *bona fide* pre-emption or homestead claim upon agricultural lands, or authorize the sale of the improvements of any *bona fide* settler to any purchaser

SEC 13. *And be it further enacted*, That where said person or association, they and their grantors, shall have held and worked their said claims a period equal to the time prescribed by the statute of limitations for mining claims of the State or Territory where the same may be situated. evidence of such possession and working of the claims for such period shall be sufficient to establish a right to a patent thereto under this Act, in the absence of any adverse claim: *Provided, however*, That nothing in this Act shall be deemed to impair any lien which may have attached in any way whatever to any mining claim or property thereto attached prior to the issuance of a patent.

56. It will be observed that that portion of the first proviso to said twelfth section which requires placer claims upon surveyed lands to conform to legal subdivisions, is repealed by the present statute with regard to claims heretofore located, but that where such claims are located previous to survey and *do not* conform to legal subdivisions, survey, plat and entry thereof may be made according to the boundries fixed by local rule, but that where such claims *do* conform to legal subdivisions, the entry may be effected according to such legal subdivisions without the necessity of further survey or plat.

57. In the second proviso to said twelfth section, authority is given for the subdivision of forty-acre legal subdivisions into *ten-acre* lots, which is intended for the greater convenience of miners in segregating their claims both from one another and from intervening agricultural land.

58. It is held therefore, that under a proper construction of the law these ten-acre lots in mining districts should be considered and dealt with, to all intents and purposes, as legal subdivisions, and that an applicant having a legal claim which conforms to one or more of these ten-acre lots, either adjoining or cornering, may make entry thereof, after the usual proceedings, without further survey or plat.

59. In cases of this kind, however, the notice given of the application must be very specific and accurate in description, and as the forty-acre tracts may be subdivided into ten-acre lots, either in the form of squares of ten by ten chains, or of parallelograms five by twenty chains, so long as the lines are parallel and at right angles with the lines of the public surveys, it will be necessary that the notice and application state specifically what ten acre lots are sought to be patented, in addition to the other *data* required in the notice.

60. Where the ten acre subdivision is in the form of a square it may be described, for instance, as the "S. E. ¼ of the S. W. ¼ of N. W ¼," or, if in the form of a parallelogram as aforesaid, it may be described as the "W. ½ of the

W. ½ of the S. W. ¼ of the N. W. ¼ (or the N. ½ of the S. ½ of the N. E. ¼ of the S. E. ¼) of section ——, township ——, range ——," as the case may be; but, in addition to this description of the land, the notice must give all the other data that is required in a mineral application, by which parties may be put on inquiry as to the premises sought to be patented.

61. The proceedings necessary for the adjustment of rights where a known vein or lode is embraced by a placer-claim, are so clearly defined in the eleventh section of the Act as to render any particular instructions upon that point at this time unnecessary.

62. When an adverse claim is filed to a placer application, the proceedings are the same as in the case of vein or lode claims, already described.

QUANTITY OF PLACER GROUND SUBJECT TO LOCATION.

63. By the twelfth section of said amendatory Act of July 9, 1870 (third proviso,) it is declared "that no location of a placer-claim hereafter made shall exceed one hundred and sixty acres for any one person or association of per sons, which location shall conform to the United States surveys," etc.

64. The tenth section of the Act of May 10, 1872, provides that "all placer-mining claims hereafter located shall conform as near as practicable with the United States system of public land surveys, and the rectangular subdivisions of such surveys, and no such locations shall include more than twenty acres for each individual claimant."

65. The foregoing provisions of law are construed to mean that after the 9th day of July, 1870, no location of a placer-claim can be made to exceed one hundred and sixty acres, whatever may be the number of locators associated together, or whatever the local regulations of the district may allow; and that from and after the passage of said Act of May 10, 1872, no location made by an individual can exceed twenty acres, and no location made by an association of individuals can exceed one hundred and sixty acres, which location of one hundred and sixty acres cannot be made by a less number than eight *bona fide* locators, but that whether as *much* as twenty acres can be located by an individual, or one hundred and sixty acres by an association, depends entirely upon the mining regulations in force in the respective districts at the data of the location; it being held that such mining regulations are in no way enlarged by said acts of Congress, but remain intact and in full force with regard to the full size of locations, in so far as they do not permit locations in excess of the limits fixed by Congress, but that where such regulations permits locations in excess of the maximums fixed by Congress as aforesaid, they are restricted accordingly.

66. The regulations hereinbefore given as to the manner of marking locations on the ground, and placing the same on record, must be observed in the case of placer locations, so far as the same are applicable; the law requiring, however, that where placer claims are upon *surveyed* public lands, the locations must hereafter be made to conform to legal subdivisions thereof.

67. With regard to the proofs necessary to establish the possessory right to a placer claim, the said thirteenth section of the Act of July 9, 1870, provides that "where said person or association, they and their grantors, shall have held and worked their said claims for a period equal to the time prescribed by the statute of limitations for mining claims for the State or Territory where the same may be situated, evidence of such possession and working of the claims for such period shall be sufficient to establish a right to a patent thereto under this Act in the absence of any adverse claim."

68. This provision of law will greatly lessen the burden of proof, more especially in the case of old claims located many years since, the records of which, in many cases, have been destroyed by fire, or lost in other ways during the lapse of time, but concerning the possessory right to which all controversy or litigation has long been settled.

69. When an applicant desires to make his proof of possessory right in accordance with this provision of law, you will not require him to produce evidence of location, copies of conveyances, or abstracts of title, as in other cases, but will require him to furnish a duly certified copy of the statute of limitations of mining claims for the State and Territory, together with his sworn statement giving a clear and succinct narration of the facts as to the origin of his title, and likewise as to the continuation of his possession of the mining

ground covered by his application; the area thereof, the nature and extent of the mining that has been done thereon; whether there has been any opposition to his possession or litigation with regard to his claim; and if so, when the same ceased; whether such cessation was caused by compromise or by judicial decree, and any additional facts within the claimant's knowledge having a direct bearing upon his possession and *bona fides* which he may desire to submit in support of his claim.

70. There should likewise be filed a certificate under seal of the court having jurisdiction of mining cases within the judicial district embracing the claim, that no suit or action of any character whatever involving the right of possession to any portion of the claim applied for is pending, and that there has been no litigation before said court affecting the title to said claim or any part thereof for a period equal to the time fixed by the statute of limitations for mining claims in the State or Territory as aforesaid, other than that which has been finally decided in favor of the claimant.

71. The claimant should support his narrative of facts relative to his possession, occupancy, and improvements by corroborative testimony of any disinterested person or persons of credibility who may be cognizant of the facts in the case and are capable of testifying understandingly in the premises.

72. It will be to the advantage of claimants to make their proofs as full and complete as practicable.

APPOINTMENT OF DEPUTY SURVEYORS OF MINING CLAIMS—CHARGES FOR SURVEYS AND PUBLICATIONS—FEES OF REGISTERS AND RECEIVERS, ETC.

73. The twelfth section of the said Act of May 10, 1872, provides for the appointment of surveyors of mineral claims, authorizes the Commissioner of the General Land Office to establish the rates to be charged for surveys and for newspaper publications, prescribes the fees allowed to the local officers for receiving and acting upon applications for mining patents and for adverse claims thereto, etc.

74. The surveyors general of the several districts will, in pursuance of said law, appoint in each land district as many competent deputies for the survey of mining claims as may seek such appointment; it being distinctly understood that all expenses of these notices and surveys are to be borne by the mining claimants and not by the United States; the system of making *deposits* for mineral surveys, as required by previous instructions, being hereby revoked as regards *field-work;* the claimant having the option of employing *any* deputy surveyor within such district to do his work in the field.

75. With regard to the *platting* of the claim and other *office-work* in the Surveyor-General's office, that officer will make an estimate of the cost thereof, which amount the claimant will deposit with any United States Assistant Treasurer, or designated depository, in favor of the United States Treasurer, to be passed to the credit of the fund created by "individual depositors for surveys of the public lands," and file with the Surveyor-General duplicate certificates of such deposit, in the usual manner.

76. The surveyors general will endeavor to appoint mineral deputy surveyors, as rapidly as possible, so that one or more may be located in each mining district for the greater convenience of miners.

77. The usual oaths will be required of these deputies and their assistants as to the correctness of each survey executed by them.

78. The law requires that each applicant shall file with the Register and Receiver a sworn statement of all charges and fees paid by him for publication of notice and for survey; together with all fees and money paid the Register and Receiver, which sworn statement is required to be transmitted to this office, for the information of the Commissioner.

79. Should it appear that excessive or exhorbitant charges have been made by any surveyor or any publisher, prompt action will be taken with the view of correcting the abuse.

80. The fees payable to the Register and Receiver, for filing and acting upon applications for mineral land patents, made under said Act of May 10, 1872, are five dollars for each officer, to be paid by the applicant for patent at the time of filing, and the like sum of five dollars is payable to each officer by an adverse claimant at time of filing his adverse claim.

81. All fees or charges under this Act, or the acts of which it is amendatory, may be paid in United States currency.

82. The Register and Receiver will, at the close of each month, forward to this office an abstract of mining applications filed, and a register of receipts, accompanied with an abstract of mineral lands sold.

83. The fees and purchase money received by Registers and Receivers must be placed to the credit of the United States in the Receiver's monthly and quarterly account, charging up in the disbursing account the sums to which the Register and Receiver may be respectively entitled as fees and commissions, with limitations in regard to the legal maximum.

84. The thirteenth section of the said Act of May 10, 1872, provides that all affidavits required under said Act, or the Act of which it is amendatory, may be verified before *any* officer authorized to administer oath within the land district where the claims may be situated, in which case they will have the same force and effect as if taken before the Register or Receiver, and that in cases of contest as to the mineral or agricultural character of land, the testimony and proofs may be taken before any such officer on personal notice of at least ten days to the opposing party, or if said party cannot be found, then, after publication of notice for at least once a week for thirty days, in a newspaper, to be designated by the Register as published nearest to the location of such land, proof of which notice must be made to the Register.

85. The instructions heretofore issued with regard to disproving the mineral character of lands are accordingly modified so as to allow proof upon *that point* to be taken before *any* officer authorized to administer oaths within the land district, and that where the residence of the parties who claim the land to be mineral is known, such evidence may be taken without publication, ten days after the mineral claimants or affiants shall have been personally notified of the time and place of such hearing; but in cases where such affiants or claimants cannot be served with personal notice, or where the land applied for is returned as mineral upon the township plat, or where the same is now or may hereafter be suspended for non-mineral proof, by order of this office, then the party who claims the right to enter the land as agricultural will be required, at his own expense, to publish a notice once each week for five consecutive weeks in the newspaper of the largest circulation published in the county within which said land is situated, or if no newspaper is published within such county, then in a newspaper published in an adjoining county; the newspaper in either case to be designated by the Register; which notice must be clear and specific, embracing the points required in notices under instructions from this office of March 20, 1872, and must name a day after the last day of publication of such notice, when testimony as to the character of the land will be taken, stating before what magistrate or other officer such hearing will be had, and the place of such hearing.

MILL-SITES.

86. The fifteenth section of said Act provides, "That where non-mineral land not contiguous to the vein or lode is used or occupied by the proprietors of such vein or lode for mining or milling purposes, such non-adjacent surface ground may be embraced and included in an application for a patent for such vein or lode, and the same may be patented therewith, subject to the same preliminary requirements as to survey and notice as are applicable under this Act to veins or lodes: *Provided*, That no location hereafter made of such non-adjacent land shall exceed five acres, and payment for the same must be made at the same rate as fixed by this Act for the superficies of the lode. The owner of a quartz-mill or reduction works, not owning a mine in connection therewith, may also receive a patent for his mill-site as provided in this section."

87. To avail themselves of this provision of law, parties holding the possessory right to a vein or lode, and to a piece of land not contiguous thereto, for mining or milling purposes, not exceeding the quantity allowed for such purposes by the local rules, regulation, or customs, the proprietors of such vein or lode may file in the proper land office their application for a patent, under oath, in manner already set forth herein, which application, together with the plat and field-notes, may include, embrace, and describe in addition to the vein or lode, such non-contiguous mill-site, and after due proceedings as to notice, etc., a patent will be issued conveying the same as one claim.

88. In making a survey in a case of this kind, the lode claim should be described in the plat and field notes as "Lot No. 37, A," and the mill-site as "Lot No. 37, B," or whatever may be its appropriate numerical designation; the course and distance from a corner of the mill-site to a corner of the lode claim to be invariably given in such plat and field notes, and a copy of the plat and notice of application for patent must be conspicuously posted upon the mill-site as well as upon the vein or lode for the statutory period of sixty days. In making the entry no separate receipt or certificate need be issued for the mill-site, but the whole area of both lode and mill-site will be embraced in one entry, the price being five dollars for each acre and fractional part of an acre embraced by such lode and mill-site claim.

89. In case the owner of the quartz-mill or reduction works is not the owner or claimant of a vein or lode, the law permits him to make application therefor in the same manner prescribed herein for mining claims, and after due notice and proceedings, in the absence of a valid adverse filing, to enter and receive a patent for his mill-site, at said price per acre.

90. In every case there must be a satisfactory proof that the land claimed as a mill-site is not mineral in character, which proof may, where the matter is unquestioned, consist of the sworn statement of the claimant, supported by that of one or more disinterested persons capable from acquaintance with the land to testify understandingly.

91. The law expressly limits mill-site locations made from and after its passage to *five acres*, but whether so *much* as that can be located depends upon the local customs, rules, or regulations.

92. The Registers and Receivers will preserve an unbroken consecutive series of numbers for all mineral entries.

PROOF OF CITIZENSHIP OF MINING CLAIMANTS.

93. The proof necessary to establish the citizenship of applicants for mining patents, whether under the present or past enactments, it will be seen by reference to the seventh section of this Act under consideration, may consist, in the case of an individual claimant, of his own affidavit of the fact; in the case of an association of persons *not* incorporated, of the affidavit of their authorized agent, made on his own knowledge or upon information and belief, that the several members of such association are citizens; and in the case of an incorporated company, organized under the laws of the United States, or the laws of any State or Territory of the United States, by the filing of a certified copy of their character or certificate of incorporation.

94. These affidavits of citizenship may be taken before the Register or Receiver, or any other officer authorized to administer oaths within the district.

95. Copies of the previous mining statutes of Congress, dated respectively July 26, 1866, and July 9, 1870, are hereto attached. Sections one, two, three, four and six of the former being expressly repealed by the ninth section of the Act of May 10, 1872, aforesaid, which in its sixteenth section also repeals all Acts and parts of Acts inconsistent with its provisions.

96. The foregoing will be followed in due time by such further instructions as actual experience in the administration of the statute may render necessary.

Very respectfully, your obedient servant,

WILLIS DRUMMOND, Commissioner.

To Registers and Receivers, and Surveyors General.

A.—CHAP. CCLXII.

AN ACT GRANTING THE RIGHT OF WAY TO DITCH AND CANAL OWNERS OVER THE PUBLIC LANDS, AND FOR OTHER PURPOSES.

Be it enacted by the Senate and House of Representatives of the United States of America in Congress assembled, That the mineral lands of the public domain, both surveyed and unsurveyed, are hereby declared to be free and open to exploration and occupation by all citizens of the United States, and those who have declared their intention to become citizens, subject to such regulations as may be prescribed by law, and subject also to the local customs or rules of the miners in the several mining districts, so far as the same may not be in conflict with the laws of the United States. [Repealed.]

SEC. 2. *And be it further enacted*, That whenever any person, or association of persons, claim a vein or lode of quartz, or other rock in place, bearing gold, silver, cinnabar, or copper, having previously occupied and improved the same according to the local customs or rules of miners in the district where the same is situated, and having expended in actual labor and improvements thereon an amount of not less than one thousand dollars, and in regard to whose possession there is no controversy or opposing claim, it shall and may be lawful for said claimant, or association of claimants, to file in the local land office a diagram of the same, so extended latterly or otherwise as conform to the local laws, customs, and rules of miners, and to enter such tract and receive a patent therefor, granting such mine, together with the right to follow such vein or lode with its dips, angles, and variations to any depth, although it may enter the land adjoining, which land adjoining shall be sold subject to this condition. [Repealed.]

SEC. 3. *And be it further enacted*, That upon the filing of the diagram as provided in the second section of this Act, and posting the same in a conspicuous place on the claim, together with a notice of intention to apply for a patent, the Register of the land office shall publish a notice of the same in a newspaper published nearest to the location of said claim, and shall also post such notice in his office for the period of ninety days; and after the expiration of said period, if no adverse claim shall have been filed, it shall be the duty of the Surveyor-General, upon application of the party, to survey the premises and make a plat thereof, indorsed with his approval, designating the number and description of the location, the value of the labor and improvements, and the character of the vein exposed; and upon the payment to the proper officer of five dollars per acre, together with the cost of such survey, plat, and notice, and giving satisfactory evidence that the diagram and notice have been posted on the claim during said period of ninety days, the Register of the land office shall transmit to the General Land Office said plat, survey and description, and a patent shall issue for the same thereupon. But said plat, survey, or description shall in no case cover more than one vein or lode, and no patent shall issue for more than one vein or lode, which shall be expressed in the patent issued. [Repealed.]

SEC. 4. *And be it further enacted*, That when such location and entry of a mine shall be upon unsurveyed lands, it shall and may be lawful, after the extension thereto of the public surveys, to adjust the surveys to the limits of the premises according to the location and possession and plat aforesaid; and the Surveyor-General may, in extending the surveys, vary the same from a rectangular form to suit circumstances of the country and the local rules, laws, and customs of miners: *Provided*, That no location hereafter made shall exceed two hundred feet in length along the vein for each locator, with an additional claim for discovery to the discoverer of the lode, with the right to follow such vein to any depth with all its dips, variations, and angles, together with a reasonable quantity of surface for the convenient working of the same, as fixed by local rules. *And provided further*, That no person may make more than one location on the same lode, and not more than three thousand feet shall be taken in any one claim by any association of persons. [Repealed.]

SEC. 5. *And be it further enacted*, That as a further condition of sale, in the absence of necessary legislation by Congress, the local Legislature of any State or Territory may provide rules for working mines involving easements, drainage, and other necessary means to their complete development; and those conditions shall be fully expressed in the patent.

SEC. 6. *And be it further enacted*, That whenever any adverse claimants to any mine, located and claimed as aforesaid, shall appear before the approval of the survey, as provided in the third section of this Act, all proceedings shall be stayed until final settlement and adjudication, in the courts of competent jurisdiction, of the rights of possession to such claim, when a patent may issue as in other cases. [Repealed.]

SEC. 7. *And be it further enacted*, That the President of the United States be, and is hereby authorized to establish additional land districts, and to appoint the necessary officers under existing laws, whenever he may deem the same necessary for the public convenience in executing the provisions of this Act

SEC. 8. *And be it further enacted*, That the right of way for the construction of highways over public lands, not reserved for public uses, is hereby granted.

SEC. 9. *And be it further enacted*, That whenever, by priority of possession, rights to the use or water for mining, agricultural, manufacturing, or other purposes, have vested and accrued, and the same are recognized and acknowledged by the local customs, laws, and the decisions of courts, the possessors and owners of such vested rights shall be maintained and protected in the same; and the right of way for the construction of ditches and canals for the purposes aforesaid is hereby acknowledged and confirmed: *Provided, however*, That whenever, after the passage of this Act, any person or persons shall, in the construction of any ditch or canal, injure or damage the possession of any settler on the public domain, the party committing such injury or damage shall be liable to the party injured for such injury or damage.

SEC. 10. *And be it further enacted*, That wherever, prior to the passage of this Act, upon the lands heretofore designated as mineral lands, which have been excluded from survey and sale, there have been homesteads made by citizens of the United States, or persons who have declared their intention to become citizens, which homesteads have been made, improved, and used for agricultural purposes, and upon which there have been no valuable mines of gold, silver, cinnabar, or copper discovered, and which are properly agricultural lands, the said settlers or owners of such homesteads shall have a right of pre-emption thereto, and shall be entitled to purchase the same at the price of one dollar and twenty-five cents per acre, and in quantity not to exceed one hundred and sixty acres; or said parties may avail themselves of the provisions of the Act of Congress approved May twenty, eighteen hundred and sixty-two, entitled "An Act to secure homesteads to actual settlers on the public domain," and acts amendatory thereof.

SEC. 11. *And be it further enacted*, That upon the survey of the lands aforesaid, the Secretary of the Interior may designate and set apart such portions of the said lands as are clearly agricultural lands which lands shall thereafter be subject to pre-emption and sale as other public lands of the United States, and subject to all the laws and regulations applicable to the same.

Approved July 26, 1866.

B.—CHAP. CCXXXV.

AN ACT TO AMEND "AN ACT GRANTING THE RIGHT OF WAY TO DITCH AND CANAL OWNERS OVER THE PUBLIC LANDS, AND FOR OTHER PURPOSES."

Be it enacted by the Senate and House of Representatives of the United States of America in Congress assembled, That the Act granting the right of way to ditch and canal owners over the public lands, and for other purposes, approved July twenty-six, eighteen hundred and sixty-six, be, and the same is hereby amended by adding thereto the following additional sections, numbered twelve, thirteen, fourteen, fifteen, sixteen, and seventeen, respectively, which shall hereafter constitute and form a part of the aforesaid Act:

SEC. 12. *And be it further enacted*, That claims, usually called "placers," including all forms of deposits excepting veins of quartz, or other rock in place, shall be subject to entry and patent under this Act, under like circumstances and conditions, and upon similar proceedings, as are provided for vein or lode claims: *Provided*, That where the lands have been previously surveyed by the United States, the entry in its exterior limits shall conform to the legal subdivisions of the public lands, no further survey or plat in such case being required, and the lands may be paid for at the rate of two dollars and fifty cents per acre: *Provided further*, That legal subdivisions of forty acres may be subdivided into ten-acre tracts; and that two or more persons, or associations of persons, having contiguous claims of any size, although such claims may be less than ten acres each, may make joint entry thereof: *And provided further*, That no location of a placer claim, hereafter made, shall exceed one hundred and sixty acres for any one person or association of persons, which location shall conform to the United States surveys; and nothing in this section contained shall defeat or impair any *bona fide* pre-emption or homestead claim upon agricultural lands, or

authorize the sale of the improvements of any *bona fide* settler to any purchaser.

SEC. 13. *And be it further enacted*, That where said person or association, they and their grantors, shall have held and worked their said claims for a period of equal to the time prescribed by the statute of limitations for mining claims of the State or Territory where the same may be situated, evidence of such possession and working of the claims for such period shall be sufficient to establish a right to a patent thereto under this Act, in the absence of any adverse claim: *Provided, however*, That nothing in this Act shall be deemed to impair any lien which may have attached in any way whatever to any mining claim or property thereto attached prior to the issuance of a patent.

SEC. 14. *And be it further enacted*, That all *ex parte* affidavits required to be made under this Act, or the Act of which it is amendatory, may be verified before any officer authorized to administer oaths within the land district where the claims may be situated..

SEC. 15. *And be it further enacted*, That Registers and Receivers shall receive the same fees for their services under this Act as are provided by law for like services under other Acts of Congress; and that effect shall be given to the foregoing Act according to such regulations as may be prescribed by the Commissioner of the General Land Office.

SEC. 16. *And be it further enacted*, That so much of the Act of March third, eighteen hundred and fifty-three, entitled "An Act to provide for the survey of the public lands in California, the granting of pre-emption rights, and for other purposes," as provides that none other than township lines shall be surveyed where the lands are mineral, is hereby repealed. And the public surveys are hereby extended over all such lands: *Provided*, That all subdividing of surveyed lands into lots less than one hundred and sixty acres may be done by county and local surveyors at the expense of the claimants: *And provided further*, That nothing herein contained shall require the survey of waste or useless lands.

SEC. 17.. *And be it further enacted*, That none of the rights conferred by sections five, eight, and nine of the Act to which this Act is amendatory shall be abrogated by this Act, and the same are hereby extended to all public lands affected by this Act; and all patents granted, or pre-emption or homesteads allowed, shall be subject to any vested and accrued water rights, or rights to ditches and reservoirs used in connection with such water rights as may have been acquired under or recognized by the ninth section of the Act of which this Act is amendatory. But nothing in this Act shall be construed to repeal, impair, or in any way affect the provisions of the "Act granting to A. Sutro the right of way and other privileges to aid in the construction of a draining and exploring tunnel to the Comstock lode, in the State of Nevada," approved July twenty-fifth, eighteen hundred and sixty-six.

Approved July 9, 1870.

Amendment to Section 5, Mining Law of May 10, 1872.

AN ACT TO AMEND AN ACT ENTITLED "AN ACT TO PROMOTE THE DEVELOPMENT OF THE MINING RESOURCES OF THE UNITED STATES.

Be it enacted by the Senate and House of Representatives of the United States in Congress assembled, That the provisions of the fifth section of the Act entitled "An Act to promote the development of the mining resources of the United States," passed May tenth, eighteen hundred and seventy-two, which requires expenditures of labor and improvements on claims located prior to the passage of said Act, are hereby so amended that the time for the first annual expenditure on claims located prior to the passage of said Act shall be extended to the tenth day of June, eighteen hundred and seventy-four.

Approved, March 1, 1873.

Department of State, Washington, March 7, 1873.

(A true copy.) R. S. CHEW, Chief Clerk.

The following Tables are taken from Scribner's Mechanics' Companion.

TABLE OF SPECIFIC GRAVITIES.

Divide the Specific Gravity by 16, and the quotient is the weight of a cubic foot in lbs.	Specific Gravity.	Weight of a cub. foot in	W't. of a cub. in. in	W't of cub. in.
METALS.		LBS.	OZ.	LBS.
Antimony,	6.712	419.50	3.883	.244
Arsenic,	5.763	360.19	3.335	.208
Bismuth,	9.823	614.00	5.684	.355
Brass, common,	7.820	489.	4.525	.282
Bronze, gun metal,	8.700	543.75	5.034	.315
Copper, cast,	8.788	549.25	5.085	.317
wire drawn	8.878	543.90	5.137	.320
Gold, pure, cast,	19.258	1203.60	11.145	.697
hammered	19.361	1210.10	11.204	.700
22 carats fine,	17.486	1093.	10.118	.633
20 carats fine	15.709	982.	9.091	.568
Iron, cast,	7.207	450.44	4.170	.260
bars,	7.788	486.81	4.507	.281
Lead, cast,	11.352	709.50	6.568	.410
Mercury, 32°	13.598	849.87	7.869	.492
60°,	13.580	848.75	7.858	.491
Platinum, rolled,	22.069	1379.31	12.771	.798
hammered,	20.337	1271.1	11.769	.736
Silver, pure, cast,	10.474	654.62	6.061	.379
hammered,	10.511	657.0	6.082	.381
Steel, soft,	7.833	489.56	4.533	.283
temp'd and hardened,	7.818	488.62	4.524	.283
Tin, Cornish,	7.291	455.62	4.219	.263
Zinc, cast,	6.861	428.81	4.970	.248
STONES AND EARTHS.				
Alabaster, white,	2.730	170.62	1.580	.099
yellow	2.699	167.44	1.562	.098
Amber,	1.078	67.37	.623	.039
Asbestos, starry	3.073	192.06	1.778	.111
Brick	1.900	118.75	1.099	.069
Chalk,	2.784	174.	1.611	.100
Charcoal,	.441	27.56	.025	.016
triturated,	1.380	86.25	.798	.050
Clay,	1.930	120.62	1·116	.070
common soil,	1.984	124.	1.148	.071
Coal, bituminous,	1.270	79.37	.735	.046
Newcastle,	1.270	79.37	.735	.046
Scotch,	1.300	81.25	.752	.047
Maryland,	1.355	84.69	.784	.049
Anthracite,	1.436	89.75	.831	.052
	1.640	102 50	.949	.059
Diamond,	3.521	220.06	2.037	.127
Earth, loose,	1.500	93.75	.868	.054
Emery,	4.000	250.	2.314	.144
Flint, black,	2.582	161.37	1.494	.094
white,	2.594	162.12	1.501	.094
Granite, Scotch,	2.625	164,06	1.519	.095
Susquehanna,	2.704	169.	1.565	.098
Quincy,	2.652	165.75	1.534	.097
Patapsco,	2.640	165.	1.527	.096
Lockport,	2.655	166.	1.566	.098

TABLE OF SPECIFIC GRAVITIES.

Divide the Specific Gravity by 16, and the quotient is the weight of a cubic foot in lbs.	Specific Gravity.	Weight of a cub. foot in	W't of a cub. in. in	W't of cub. in.
		LBS.	OZ.	LBS.
Grindstone,	2.143	133.93	1.240	.077
Gypsum, opaque,	2.168	135.50	1.254	.077
Hone, white, razor,	2.876	179.75	1.664	.104
Limestone, green,	3.180	198.75	1.840	.115
white,	3.156	197.25	1.826	.114
Lime, compact,	2.720	170.0	1.574	.098
foliated,	2.837	177.4	1.642	.102
Lime, quick,	.804	50.43	.465	.029
Manganese	7.000	437.50	4.051	.252
Marble, African,	2.708	169.25	1.567	.098
Egyptian,	2.668	166.75	1.544	.097
Parian,	2.838	177.37	1.642	.103
common,	2.686	166.75	1.554	.097
French,	2.649	165.56	1.533	.096
white Italian,	2.708	169.25	1.567	.098
Rutland, Vermont,	2.708	169.30	1.567	.098
Castleton,	2.673	167.	1.546	.097
Stockbridge,	2.669	166.86	1.545	.097
Mica,	2.800	175.	1.620	.100
Millstone,	2.484	155.25	1.431	.090
Porcelain, China	2.385	149.	1.322	.086
Pumice Stone,	.915	57.18	.530	.033
Paving Stone,	2.416	151.	1.398	.088
Porphyry, red,	2.765	172.81	1.600	.099
Rotten Stone,	1.981	123.81	1.146	.071
Sand	1.800	112.50	1.041	.065
Shale,	2.600	162.50	1.504	.095
Slate,	2.672	167.	1.546	.097
Stone, Bristol,	2·510	156.87	1.452	.091
common,	2.520	·157.50	1.458	091

MELTING POINTS OF SOLIDS.

Platinum, palladium, rhodium, lime, silex, fine porcelain, can be melted in small quantities by strong lenses, or the hydro-oxygen blowpipe. * * *Plaster of Paris, common pottery,* at 150° to 180° of Wedgewood's pyrometer; say 20,000° to 24,000° Fahr. *Iron, red hot* (in day light), 1207° Fahr.=1° Wedgewood.

		Fahr.	Wedgewood.
	*Gold	5,237°	= 30°
	*Silver	4,717°	= 28°
	*Copper	4,587°	= 27°
	Brass	3,809°	= 21°
	Flint glass	2,377°	= 10°
	Antimony	809°	
	Cast iron	2780°	
	Zinc	680°	
	Lead	612°	Experiments of committee of the Franklin Institute.
	Bismuth	506°	
	Tin	442°	
Alloys.	Lead 2, Tin 1 (common solder)	475°	
Alloys.	Lead 1, Tin 1	393°	
Alloys.	Lead 1, Tin 2 (soft solder)	360°	
Alloys.	Lead 1, Tin 1, Bismuth 1	272°	
Alloys.	Lead 2, Tin 3, Bismuth 5	212°	

* The authorities expose absurd variations, for the high temperatures of fusion, of the following metals; where gold is by some placed at 2192°, copper at 2060°, and silver at from 1000° upwards; but it may be practically stated that gold melts at *almost white heat,* copper at *strong red,* and silver at a *full red;* whilst pure wrought iron requires the strongest heat of the wind furnace. —[The Author.

TABLE OF THE COHESIVE FORCE OF METALS, ETC.

Weight or Force necessary to tear asunder 1 Square inch, in Avoirdupois Pounds.

METALS.

	LBS.		LBS.
Copper, cast,	22.500	Iron, medium bar,	60.000
wire,	61.200	inferior bar,	30.000
Gold, cast,	20.450	Lead, cast,	.880
wire,	30.888	milled,	3.320
Iron, cast; grey, 2 fusion,	30.680	Platinum, wire,	53.000
English,	52.000	Silver, cast,	41.000
French,	70.000	wire,	38.257
French, soft,	63.600	Steel, soft,	120.000
German,	68.300	fine,	135.000
Iron, wrought,	60.000	razor, tempered,	150.000
Swedish,	72.000	Tin, cast block,	5.000
English,	55.872	Zinc, cast,	2.600
German,	69.000	sheet,	16.000
Iron, wire,	{ 85.700 113.		

Strength of Alloys when pulled in the direction of their Length.

PARTS.	PARTS.	LBS.	PARTS.	PARTS.	LBS.
Gold 5,	Copper 1,	50.000	Silver 5,	Copper 1,	48,000
Brass,		45.000	4,	Tin 1,	41.000
Copper 10,	Tin 1,	32.000	Tin 10,	Antimony 1,	11.000
8,	1,	36.000	10,	Zinc 1,	12.914
4,	1,	35.000	10,	Lead 1,	6.800
Bronze (gun metal),		30.000			

WOODS.

	LBS.		LBS.
Ash, white, seasoned	14.000	Mahogany,	21.800
red, seasoned	17.800	Spanish	12,000
Birch,	15.000	Maple,	10,500
Bay,	14 500	Oak, American, white.	11.500
Beech,	11.500	English,	10.000
Box,	20.000	seasoned,	13.600
Cedar,	11.400	Pine, pitch	12.000
Chestnut, sweet	10.500	Norway,	13.000
Cypress,	6.000	Poplar	7.000
Deal, Christiana	12.400	Quince	6,000
Elm,	13·400	Sycamore	13.000
Fir, strongest	12.000	Teak, Java	14.000
American,	8.800	Walnut,	17.800
Lance wood,	24.000	Willow,	13.000
Lignum vitæ,	11.800	Yew	8.000
Locust,	20.500		

MISCELLANEOUS SUBSTANCES.

Brick,	.290	Mortar, 20 years,	52
Glass plate	9.400	Slate,	12.000
Hemp fibres glued together	92.000	Stone, fine grain,	.200
Ivory,	16.000	Whalebone	7.600
Marble	9.000		

HOW THE LOSS OF SILVER, UNDER WATER TREATMENT, CAN BE PREVENTED; AND NATURALLY POOR ORES, BE MADE TO REALIZE PROFITS, BY HAND ASSORTMENT, DRY CRUSHING, SIEVE SEPARATION, AND CONCENTRATION.

The reader has been already cautioned, at page 534, against the use of *surplus water* when crushing the *soft and very friable silver ores;* and also at pages 472, and 476, for modes of treatment of certain base minerals; where *dry crushing and concentration* are imperatively essential. Being still more than ever convinced, that such means may often be advantageously employed, for the beneficial treatment of silver ores, more especially where water cannot be obtained, I now call your attentien to the following several dry methods.

1. "Hand concentration," or separation of the coarse ore from the gangue by the fingers, into different heaps, as described at page 472. This has been generally practiced for improving the quality of the base minerals, but it is seldom beneficial for silver, which is more sparsely disseminated in the rock.

2. For silver ores, where the rich mineral is always very soft, and therefore broken to an impalpable powder much sooner than its hard worthless matrix, you will be generally enabled to realize great benefit by first *crushing the dry ore* in the Cornish rolls (page 460) to about the maximum size of barley corns, and then amalgamating *only the very fine more mineralized portion which passes through the seive*, instead of the whole amount.

By this simple but effective operation, you may secure nearly all the value in very much less weight, and by thus excluding much worthless rock, realize profits from veins that would be totally worthless, when worked in the usual manner. The size the rock should be crushed will vary in different ores, but it may be readily ascertained by *preliminary assays* from the siftings of *correspondingly sized* hand sieves.

3. By dry crushing, and properly regulated blast, which propels the debris forward from the battery, to deposit according to size and specific gravity, into *more or less distant*, settling chambers.

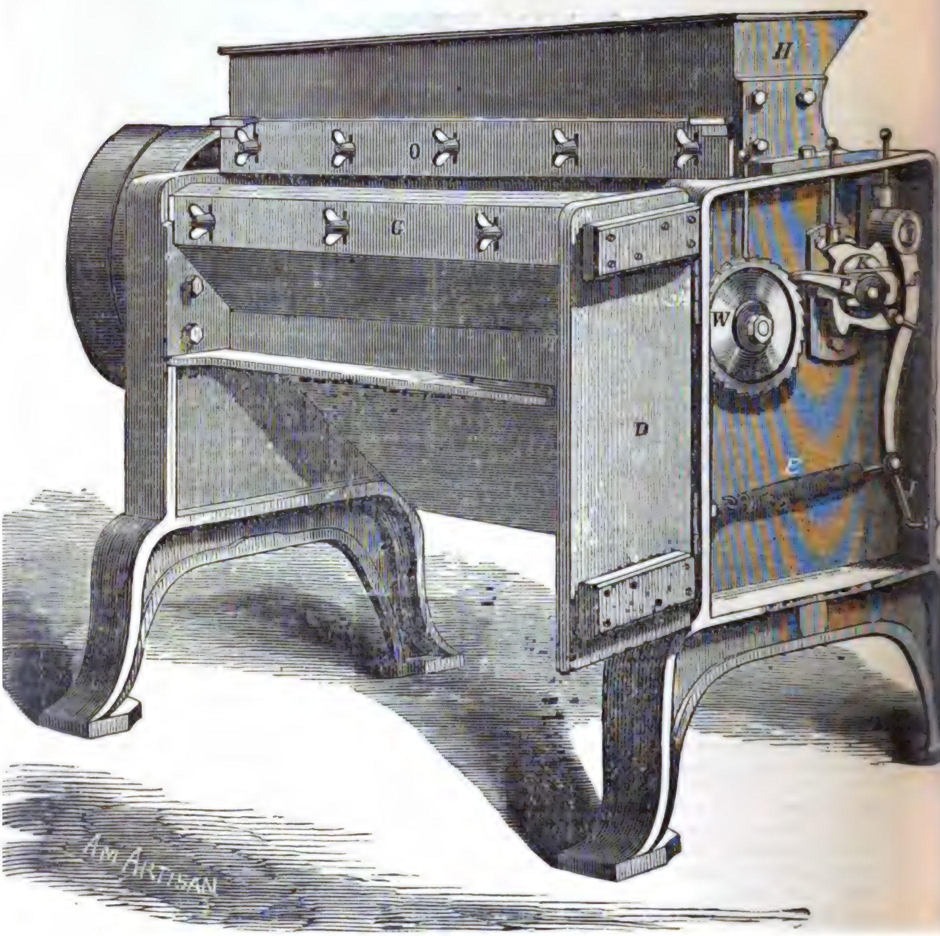
4. By treating the dry finely pulverized ores, in *pneumatic* jigging machines of similar construction to those worked by intermittent oscillations of water, as moved by a plunger pump, so as to be enabled to *scrape* the lighter refuse of gangue away from the surface.

5. KROM'S PATENT DRY CONCENTRATOR.

This ingeniously contrived and very portable *continuous self discharging* jigging machine, appears to be better adapted for dry concentration, than any other. I have seen it separate *hard granular base minerals*, from its associated quartz, in a very admirable, speedy, and effectual manner; and there can be no reason why it will not concentrate ores when in still finer division, provided that the intermittent blast is *tempered for particular occasions, and catch chambers* are placed at suitable distances for the retension of the *rich impalpable dust*, which in many cases, will otherwise, be blown through the jigger and escape. The inventor has fully provided for the several contingencies, of speed of supply of the ores to the gauze jigging bed; the frequency, strength, and quantity, of air puffs; the perfect freedom for the automatic discharge of the worthless gangue; and the necessary restriction, by a fluted roller, of the fall and exit of the concentrated rich ore.

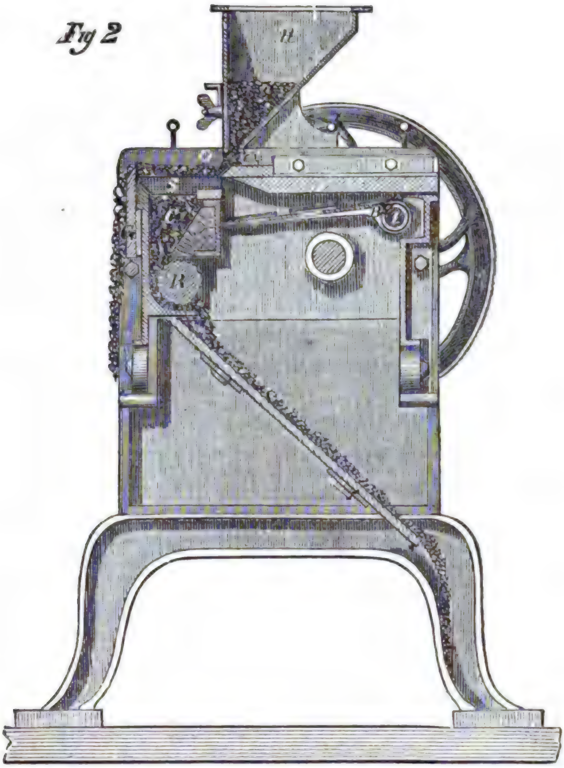
The whole machine is but five feet long, two feet wide, and four feet high. It weighs about a half ton, is screwed together in convenient pieces for packing on mules, and the wearing parts can be cheaply replaced by, intentionally made, similar duplicates. Such a machine requires about one-eighth horse power; and may be easily worked by a man, when concentrating half a ton per hour.

The following cuts represent the perspective view and transverse section of this apparatus.



"The mode of operating the machine is as follows: Ore is placed in the receiver (H), and the driving pulley set in motion. The trip-wheel (K), fixed on the opposite end of the pulley-shaft, works by its cam-shaped teeth, against the lever (A); and by the alternate action of this wheel, forcing the lever in one direction, and of the spring, which at once and suddenly carries it back again, the fan (B) is made to swing on the shaft (I), sending at each upward movement a quick and sharp puff of air through the ore-bed, and lifting slightly the ore lying on it. As there are six projections upon the trip-wheel, it follows that the moderate speed of 70 to 80 revolutions of this per minute will give 420 to 480 upward movements of the fan, in the same time, and consequently a corresponding number of puffs of air to agitate the ore. This rate is sufficient to secure a steady motion of the heavy balance pulley, and yet not so fast as to

Fig 2



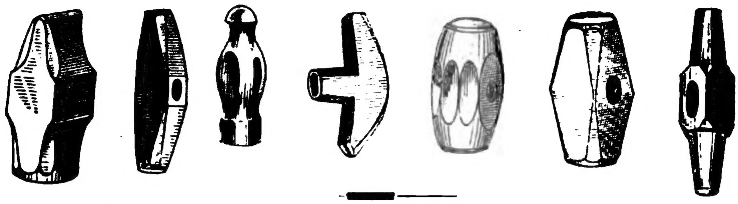
produce any unpleasant jar or noise—the machine working smoothly and easily.

The ore-bed is composed of wire-gauze tubes, placed at distances from each other of one-fourth to three-eighths of an inch, according to the grades of ore to be concentrated—the finer requiring that the tubes be set nearer together, while the coarser allow of their being farther apart. The ore-bed, situated in front of the fan, as plainly shown in the sectional view, is formed by these tubes—their ends next to the fan being open; and the air from the bellows, entering these, escapes through the top and sides of the tubes, agitating the ore that lies on them, and also that between them near the surface.

Fhe ore between the tubes rests on that immediately underneath, in the passage (C), and sinks as fast as the roller (R), at the bottom, effects its discharge. The tubes being open on the lower side, any fine ore passing through the meshes of the wire-gauze simply descends with the main body (C), thus preventing any liability of the tubes to fill up.

In discharging the concentrated ore (C), the roller (R) is operated (as mentioned above) by means of the ratchet-wheel (W), and pawl (P); and, the latter being carried by a crank on the trip-wheel, it follows that its speed is governed by the speed of this wheel, which also gives motion to the fan (B). By this connection, *the fan*, which effects the concentration, and *the roller*, which discharges the concentrated ore, are made to act *in concert* with each other. The importance of this feature will be apparent when it is remembered that the amount of ore concentrated in a given time depends on the number of puffs of air supplied per minute; so that, as the arrangement here secures, the motion of the discharge roller *should be* controlled and regulated to correspond with the speed of the fan.

To accomplish more satisfactorily the result sought, the crank which carries the pawl can also be adjusted, by varying its length, so that the speed of the roller may be further regulated, according to the richness of the ore.



NELSON & DOBLE,

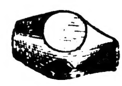
AGENTS FOR THOS. FIRTH & SON'S

CAST-STEEL

Shear, Spring, German, Plow, Blister, Toe-Calk Steel, and Files.

Manufacturers of MINERS' DRILL HAMMERS AND SLEDGES, STONE SLEDGES, EGG FACE HAMMERS, DRILL SPOONS, DOBLE'S PATENT TAMPING BARS, MILL PICKS, SLEDGES, HAMMERS, PICKS, STONE CUTTERS', BLACKSMITH'S and HORSE-SHOERS' TOOLS.

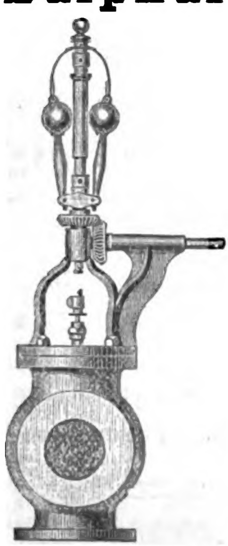
13 and 15 Fremont Street,
Near Market, : San Francisco.



HENDY'S

Latest Improved Patent Self-Discharging

Sulphurets Concentrator.



32 Fremont Street, San Francisco.

Those in want of Concentrators would do well to visit some of the quartz mills that have Hendy's Patent Concentrator in use, and satisfy themselves before purchasing other Concentrators of pretended merit. THEY ARE WARRANTED TO WORK SATISFACTORILY.

The principle upon which HENDY'S PATENT CONCEFTRATOR is constructed is the only true and mechanical one for the purpose of concentration.

CENTRIFUGAL FORCE AND GRAVITATION,

combined as they are in this Machine, CANNOT FAIL TO ACCOMPLISH the object sought.

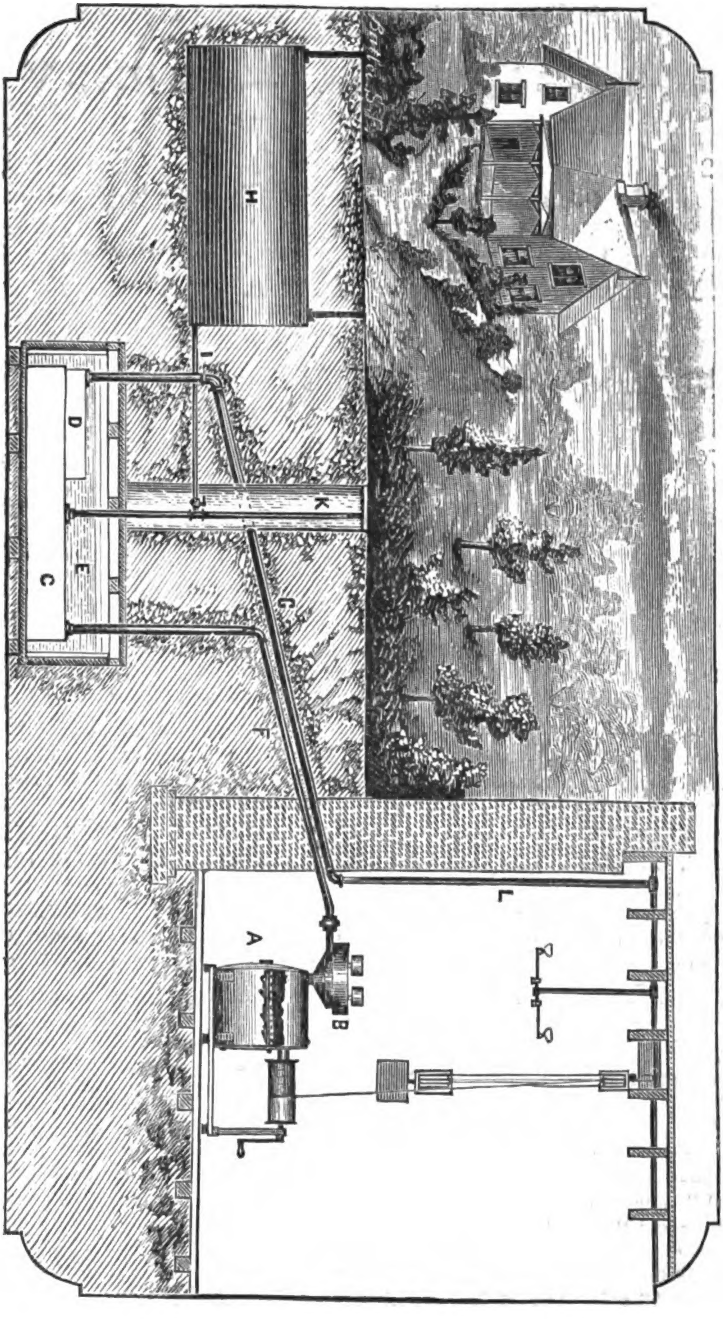
Many certificates from proprietors of mills, who have this Concentrator in use, can be had, if required, giving the most flattering accounts of its efficiency.

A most substantial evidence of its worth is that the proprietor is receiving repeated orders from those who are using them, and who have tested their merits.

The proprietor has recently still further improved the machine, making it stronger and still more durable.

☞ The Empire Mill, at Grass Valley, after using them about three years, being destroyed by fire, these **Machines were re-supplied.**

Also, Hendy's Improved Steam-engine Governor.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